northern rivers ecosystem initiative

SYNTHESIS REPORT

Canada

Alberta

Northwest Territories

NORTHERN RIVERS ECOSYSTEM INITIATIVE

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Introduction

THE NORTHERN RIVERS ECOSYSTEM INITIATIVE

In the late 1980s, northern residents became concerned about the impact of proposed industrial and resource development in the Peace, Athabasca and Slave river basins, particularly new pulp mills and associated forestry operations. As a result, the governments of Canada, Alberta and Northwest Territories got together and launched the *Northern River Basins Study* (NRBS) in 1991. The main question to be answered by the study was "What is the combined effect of all forms of development on the natural aquatic ecosystem?" The NRBS initiated research and built upon existing information to begin to understand the cumulative impacts of development. This information could then be used to plan and manage the aquatic environment in the study area.

***NRBS**: "What is the combined effect of all forms of development on the natural aquatic ecosystem?"*

Fourteen scientific questions were developed for the study (and two questions related to communication and future stakeholder involvement). Broad topics for the scientific questions included water quantity and use, water quality, fisheries and wildlife. Most northern residents wanted to know if it was safe to drink the water and eat fish out of these rivers. Therefore, a large portion of the $12.3 million allocated for the study was directed toward water quality and fish.

The NRBS used an approach that recognized the complex interrelationships among land, air, water, living organisms and human inhabitants of the basins. From the beginning of the NRBS, residents of the basin were encouraged to participate. Community consultation early in the study helped focus it and paved the way for implementing traditional knowledge as a vital part of the process. Traditional knowledge provides an important perspective and guidance for developing long-term basin management strategies.

The study found that some stretches of these rivers are being affected by human development – from pulp mill effluent, municipal sewage and the W.A.C. Bennett Dam. Fish and other aquatic organisms were experiencing stress. Toxic substances were present in a number of important fish species. Drinking water guidelines were exceeded occasionally at small water treatment facilities within the basin. These observations contributed to technological improvements and more stringent regulations. Even so, NRBS scientists discovered new challenges to the health of the aquatic ecosystem, because effects could increase with each addition of pollutants. Overall, however, the study concluded that through good management and planning, there is enough time to preserve these rivers while supporting sustainable development.

Peace River at Dunvegan (AENV)

> ***NREI:*** *"...to provide an understanding of the impacts of development on the northern river ecosystems"*

In 1996, the NRBS final report and recommendations were submitted to the three participating governments (*Northern River Basins Study Report to the Ministers*). The report provided a benchmark that defined the state of the Peace, Athabasca and Slave rivers. In 1997, the *Canada-Alberta-Northwest Territories Response to the Northern River Basins Study* was issued. This response report integrated the governments' positions and outlined future plans to ensure the long-term protection of these rivers. It confirmed the governments' commitment to pollution control and full stakeholder involvement. To address the recommendations of the NRBS, as well as the public demand for follow-up studies, the *Northern River Ecosystem Initiative* (NREI) was set up in 1998.

The NREI involved both policy initiatives and scientific research. The five-year study focussed on priorities such as pollution prevention, endocrine disruption in fish, hydrology, contaminants, nutrients, safe drinking water and enhanced environmental monitoring. Its mission was to provide the scientific underpinning to the governments' response to the recommendations of the NRBS. Its goal was to provide an understanding of the impacts of development on the northern river ecosystems.

The study included the following objectives, to be completed by 2003:

Pollution Prevention	• Promote reduction of non-point and point source pollution.
Long Range Transport of Air Pollutants	• Quantify atmospheric sources of mercury in the Athabasca River basin.
Contaminants	• Quantify the amounts of oil sands hydrocarbons entering the Athabasca River; • Identify PCB sources and implications to bioaccumulation in aquatic organisms; • Assess contaminants in fish; • Determine interactions among nutrient enrichment, contaminant effects and susceptibility of fish to low levels of dissolved oxygen.
Great Slave Lake and Slave River	• Assess the abundance of contaminants in Slave River fish and sediments; • Determine the status of fish populations in Lake Athabasca, Slave River and Great Slave Lake.
Endocrine Disrupting Substances	• Assess endocrine disrupting substances and significance to fish reproduction.
Fish Abnormalities	• Assess the incidence of fish abnormalities within the basins, especially below pulp mills.
Human Health/ Drinking Water	• Provide an overview of contaminants in fish to help guide the development of fish consumption guidelines; • Assess state of drinking water supplies for small communities; • Facilitate the certification of treatment plant operators in aboriginal communities; • Provide data to help understand implications to health of First Nations peoples.
Hydrology and Climate	• Provide information on snowmelt in the upper tributaries of the Peace River, flow regulation, climate variability and flooding of the Peace-Athabasca delta; • Document the status of the Slave River delta with respect to climate change and flow regulation; • Develop tools to predict conditions necessary to protect the Peace-Athabasca delta.
Integrated Environmental Monitoring	• Develop a system for assessing cumulative effects on aquatic ecosystems so that they may be managed; • Establish indicators and monitoring programs for the Peace-Athabasca delta; • Determine and adopt indicators to interpret monitoring programs; promote basin-wide integrated monitoring; • Adopt a database management strategy for increased public access to information.
Nutrients and Dissolved Oxygen	• Develop nutrient guidelines for the Athabasca, Smoky and Wapiti rivers to minimize excess aquatic plants and protect fish populations; • Adopt minimum dissolved oxygen guideline based on fish needs; • Develop a water quality management plan for the Smoky and Wapiti rivers.
Integrated Planning of Land and Water Use	• Develop a model to predict impacts of land clearing on hydrology and water quality; • Promote the use of existing legislation to achieve integrated land and water use planning; • Establish a baseline land cover inventory in the oil sands area.
Wildlife	• Determine the value of the Peace-Athabasca delta to shorebirds; • Improve understanding of status of waterfowl in the Peace-Athabasca delta; • Improve understanding of ecological consequences of forestry practices;
Communications and Outreach	• Inform basin residents of progress toward meeting NRBS recommendations; • Inform stakeholders of NREI studies in a timely manner; • Involve First Nations peoples in those areas of aboriginal priority; • Make sure NREI participates in existing consultative mechanisms.

NREI: *"...to provide an understanding of the impacts of development on the northern river ecosystems"*

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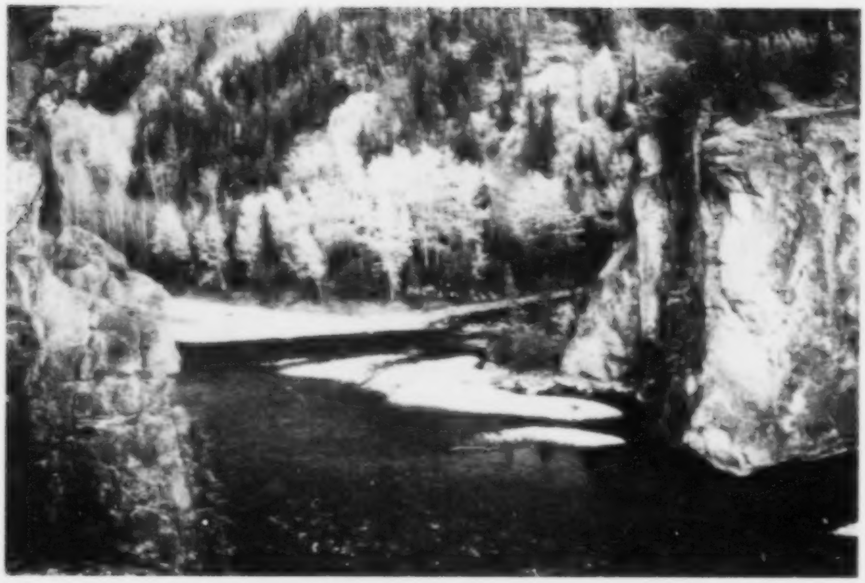
One of the recommendations of the NRBS Report to Ministers (Recommendation 1.6) was to produce a report to the public on progress in implementing recommendations. This was to be completed five years after the end of NRBS. To address this recommendation, two reports have been produced. The NREI *Final Report* lists each recommendation from the NRBS Report to the Ministers and how it was addressed. The NREI *Synthesis Report* that follows presents a summary of information gathered by the NREI. These two reports are a response by the governments to recommendations from the Northern River Basins Study.

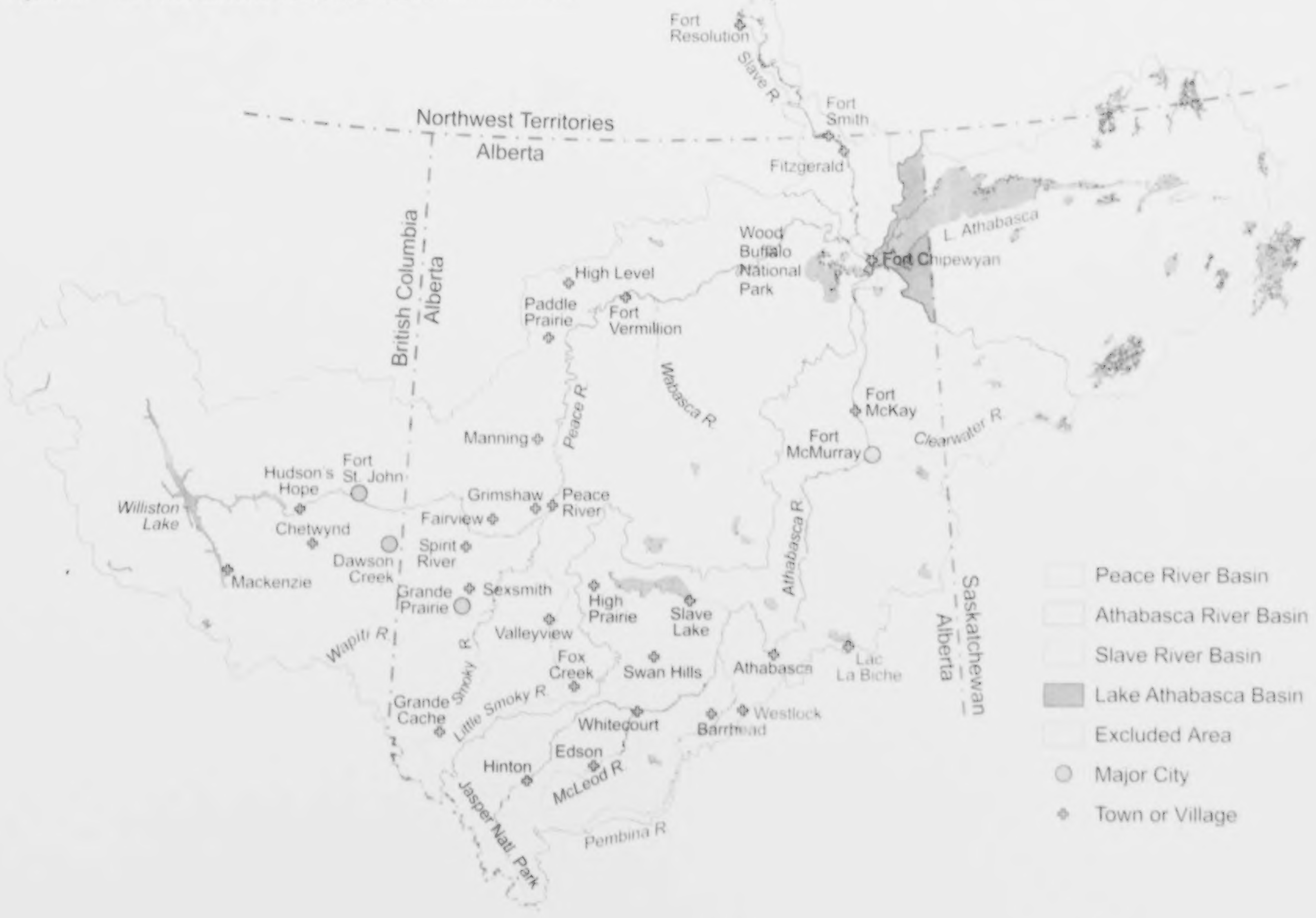
Synthesize - *to combine parts to make a coherent whole.*

This Synthesis Report builds on the information base generated during NRBS. NREI studies give a new benchmark on the present health of the northern river basins. An update on development in the basins is provided in the section entitled "The Northern River Basins." The third section, titled "How are Aquatic Ecosystems Protected?" describes initiatives, policies, partnerships, regulations, monitoring, research and other programs to protect the environment. Results of more than 20 scientific projects undertaken during the five-year study are summarized in "What New Information Was Gained from NREI?" A discussion and conclusions about what we have learned is presented in the fifth section, called "What Has Been Achieved During NREI?" If you would like further details on the projects undertaken by NREI, see the list of references. At the end of the report, you will find a glossary of terms that may be unfamiliar to you, an appendix with more information on contaminants and Internet listings for topics referred to in the report.



Smoky River at Sulphur River Inflow (AENV)

Figure 1. *The Peace-Athabasca-Slave River basins* (Environment Canada)


Fort Resolution
Slave R.
Fort Smith
Northwest Territories
Alberta
Fitzgerald
L. Athabasca
Fort Chipewyan
Wood Buffalo National Park
High Level
Paddle Prairie
Fort Vermillion
British Columbia
Alberta
Wabasca R.
Fort McKay
Fort McMurray
Clearwater R.
Manning
Peace R.
Hudson's Hope
Fort St. John
Williston Lake
Chetwynd
Dawson Creek
Grimshaw
Peace River
Fairview
Spirit River
Mackenzie
Grande Prairie
Sexsmith
High Prairie
Slave Lake
Athabasca R.
Saskatchewan
Alberta
Wapiti R.
Valleyview
Smoky R.
Fox Creek
Swan Hills
Athabasca
Lac La Biche
Grande Cache
Little Smoky R.
Whitecourt
Barrhead
Westlock
Hinton
Edson
McLeod R.
Jasper Natl. Park
Pembina R.
Peace River Basin
Athabasca River Basin
Slave River Basin
Lake Athabasca Basin
Excluded Area
Major City
Town or Village

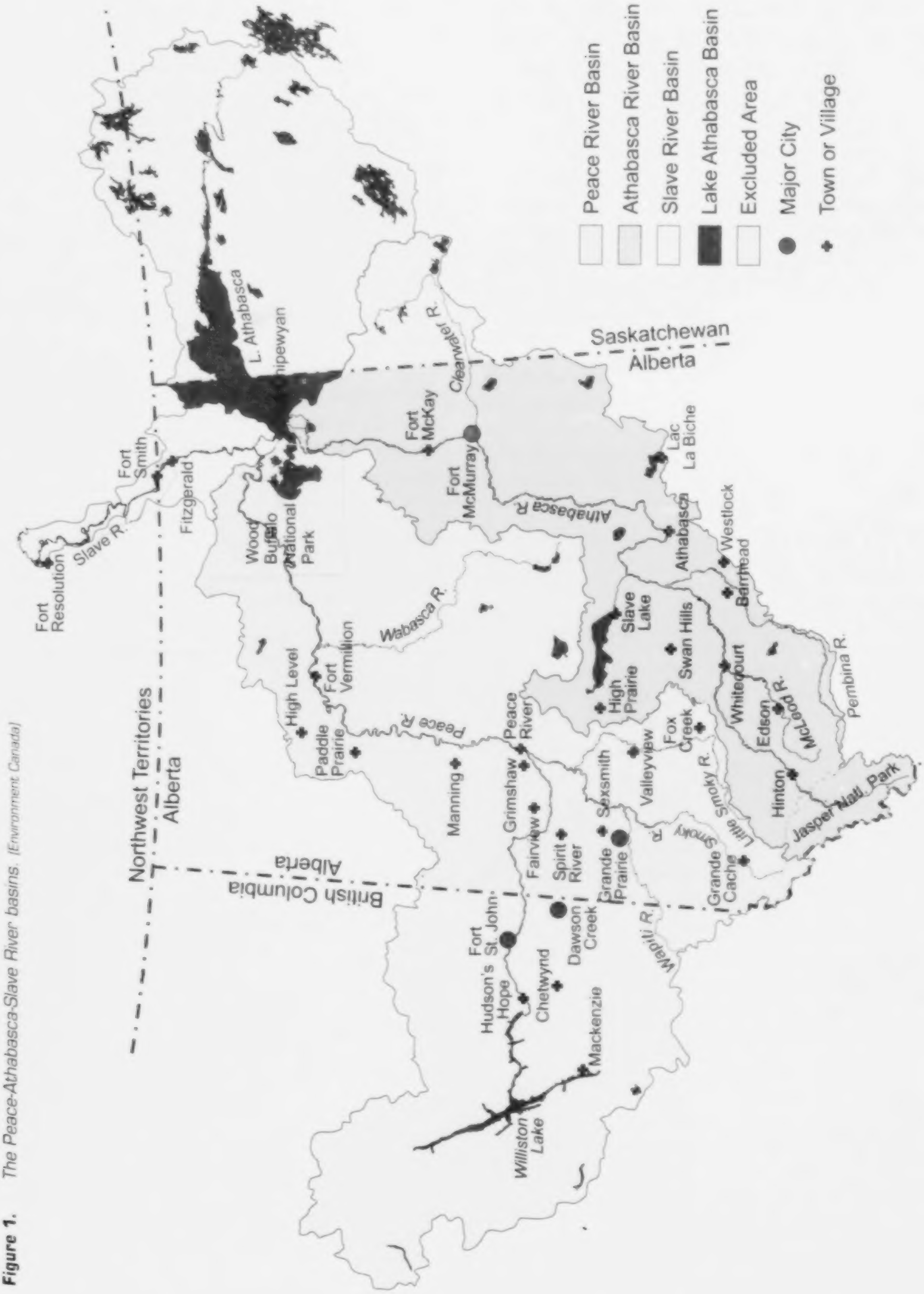

Peace River Basin
Athabasca River Basin
Slave River Basin
Lake Athabasca Basin
Excluded Area
Major City
Town or Village
Northwest Territories
Alberta
Saskatchewan
Alberta
British Columbia
Alberta
Fort Resolution
Slave R.
Fort Smith
Fitzgerald
L. Athabasca
Chipewyan
Wood Buffalo National Park
Fort McKay
Clearwater R.
Fort McMurray
Athabasca R.
Lac La Biche
Athabasca
Westlock
Barrhead
Slave Lake
Swan Hills
Whitecourt
McLeod R.
Edson
Pembina R.
Hinton
Jasper Natl. Park
Wabasca R.
High Level
Fort Vermilion
Paddle Prairie
Peace R.
Peace River
Manning
High Prairie
Fox Creek
Valleyview
Sexsmith
Grimshaw
Fairview
Spirit River
Grande Prairie
Little Smoky R.
Smoky R.
Grande Cache
Dawson Creek
Fort St. John
Hudson's Hope
Chetwynd
Wapiti R.
Mackenzie
Williston Lake

Figure 1. *The Peace-Athabasca-Slave River basins. (Environment Canada)*

The Study Area
THE NORTHERN RIVER BASINS

The *Northern Rivers Ecosystem Initiative* study area covers a vast expanse of northern Alberta and the southeast portion of the Northwest Territories. It includes the watersheds of the Peace, Athabasca and Slave rivers, excluding parts in British Columbia and Saskatchewan (*Figure 1*). Much of the resource and industrial development in the study area is in Alberta, and therefore the focus of the study is there. Details on soils, hydrology, vegetation, people and climate of these watersheds are referenced in the *Northern River Basins Study Report to the Ministers*. The following summarizes basic information and provides facts on changes that have occurred within the study area since 1996.

Peace River at town of Peace River (AENV)

Slave River at Fitzgerald (Environment Canada)

Athabasca River at Hinton (AENV)

Climate

Climate is a combination of temperature, precipitation, evaporation, wind, humidity and sunshine over the long term. The Mackenzie Basin is currently experiencing some of the greatest warming anywhere in the world, especially during the winter. Recent warming that has occurred in the Mackenzie Basin is part of a pattern of global warming that has come to be known as *climate change*. In its broadest sense, climate change refers to a change in the "average weather" for a particular region. Many scientists consider human activity to be a major cause of climate change. Because of the recent, strong warming trends in the Mackenzie Basin, there are concerns that climate change may already be impacting the basin's ecosystems and natural resources. These changes, if extended over a long period of time, could have profound effects on the terrestrial and aquatic ecosystems of the basin, not to mention the human, plant and animal populations that depend on them.

> *"Most communities in the Mackenzie River Basin reported an overall increase in temperature"*

According to the *Mackenzie River Basin State of the Aquatic Ecosystem* report, several aboriginal communities have noticed an increase in the variability of weather. Most communities in the Mackenzie River Basin reported an overall increase in temperature. People throughout the basin have reported thinner ice and have expressed concern for the danger to human travelers, migrating caribou and other wildlife. Moreover, freeze-up occurs later in the fall, breakup occurs earlier in the spring and with less force, and both processes are more gradual and take longer than in the past. During the past 20 years, water levels have decreased in lakes, rivers, and delta regions. Elders explain that these decreasing water levels result in less habitat for aquatic species such as fish, waterfowl and muskrat, and populations of these wildlife species have declined in some areas. Low water levels have interfered with fishing and travel because some traditional fishing sites are too shallow to set nets, and important boating routes are no longer navigable.

These observations are supported by temperature data for northern weather stations. Figure 2 shows average annual temperatures at Fort McMurray for 1944-2000. This station has the most complete data record of all stations in northern Alberta. Each bar on the graph is the average temperature for the year (calculated by adding all the average daily temperatures and dividing by 365 days). Most of the bars are below zero in the early years, whereas in the later years, most are above zero.

Temperatures have increased over this time period, although the increase is only a degree or two. Other stations in the northern basins also show increasing average annual temperatures (Grande Prairie, High Level, Fort Vermilion and Yellowknife). Most of the warming has occurred over the winter months, especially January to March-April. Summer temperatures have increased only very slightly, with October-November slightly cooler.

The average amount of precipitation has also changed over the past 20 years. Figure 3 shows long-term precipitation at Fort McMurray. Between 1980 and 2000 precipitation was below normal: an average of 437 mm for 1980-1990 and 431 mm for 1991-2000. The long-term average is 446 mm (57 years of data). These averages do not reflect individual events, which may produce a lot of precipitation in a short period.

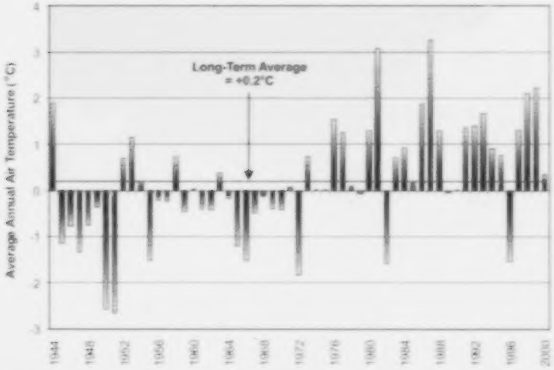


Figure 2: *Average annual air temperature at Fort McMurray, 1944-2000.* [Environment Canada]

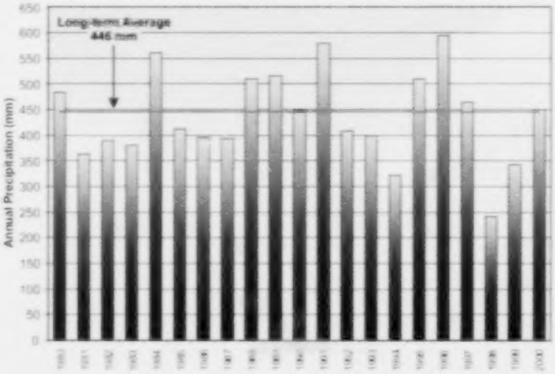


Figure 3: *Average annual precipitation at Fort McMurray, 1980-2000.* [Environment Canada]

Hydrology

The NREI study area includes three major river systems. The Peace and Athabasca rivers flow into the east end of Lake Athabasca and form the Peace-Athabasca Delta. The Slave River flows from Lake Athabasca to Great Slave Lake in the Northwest Territories (*see Figure 1*).

The Peace River begins as the outflow of BC Hydro's W.A.C. Bennett Dam in British Columbia. Measured at Peace Point, its total watershed is 293,000 square kilometres. Most of the flow (76%) originates upstream of the Alberta-British Columbia boundary.

Cubic Decametre

A cubic decametre (dam^3) equals 1000 cubic metres, or a cube 10 metres by 10 metres by 10 metres, or half a million 2 L milk jugs.

The dam impacts the Peace River by increasing flows in winter and reducing them during the spring and summer months. Another dam, Peace Canyon, is downstream but it does not regulate flow. The overall amount of water reaching Peace Point is essentially unchanged but it has been redistributed over the year. At Peace Point, upstream of the Peace-Athabasca Delta, there has been a 25-50% reduction in mean monthly summer flows and 175-250% increase in mean monthly winter flows due to regulation.

One of the major tributaries of the Peace River is the Smoky River, which drains the watersheds of the Wapiti and Little Smoky rivers, as well as a number of smaller rivers. On average, the Smoky River contributes about 11.0 million cubic decametres of water annually to the Peace River.

Athabasca River 10 km downstream of Whitecourt (AENV)

The headwaters of the Wapiti River originate in the eastern slopes of the Rocky Mountains north of Jasper National Park. The river stretches for 245 km after which it joins the Smoky River and flows north into the Peace River. The Wapiti has an average annual discharge of about 3.1 million cubic decametres.

Another major tributary is the Wabasca River, which contributes about 2.9 million cubic decametres of water to the Peace River each year. By the time the Peace River reaches Wood Buffalo Park, the flow volume has nearly doubled (66.8 million cubic decametres) compared with the flow out of from the Williston Reservoir (at Hudson Hope).

"By the time the Peace River reaches Wood Buffalo Park, the flow volume has nearly doubled..."

The Athabasca River has its origin in melting snow and glaciers of Jasper National Park in the Rocky Mountains. As it leaves the mountains, the flow volume is relatively small – an annual average of 2.5 million cubic decametres near the town of Jasper and 5.5 million cubic decametres at Hinton. By the time it reaches the town of Athabasca, it has been supplemented by flows from the McLeod, Berland, Pembina and Lesser Slave rivers. At this point the flow volume is about five times greater than at Jasper. As the Athabasca River flows northward, other rivers, such as the La Biche, Calling, House and Clearwater rivers, add to it. At Fort McMurray, the annual flow volume is 20 million cubic decametres. At this point, the watershed area is 133,000 km^2. Supplemented further by the MacKay and Firebag rivers, the Athabasca River ends in Lake Athabasca via a number of widely distributed channels through the Athabasca Delta.

Specific information on the amount that glacial meltwater contributes to flow in the Athabasca River is not available. The melting of glaciers augments baseflow and is likely most important in dry years during the late summer and early fall, when surface runoff and groundwater are not being recharged by late-season precipitation. The highest amount of glacial melt occurs during years of low snowpack, when the glaciers are not insulated by snow. During

Columbia Icefield (AENV)

high snowpack years the glacier tends to grow and snow goes into storage within the glacier. Glaciers tend to regulate the variability in runoff within watersheds where they occur. While glaciers are receding there would be a net increase in contribution to streamflow at first. If the glaciers continue to recede or disappear altogether, river flows would be reduced. There is some evidence that the increased flow phase has already peaked in the Athabasca River, and that flows from melting glaciers are declining. But because the relative contribution of glacial melt water to the river is small, it may only be significant under certain hydrologic conditions, such as during low runoff years and in late summer.

During the NREI study years, flow volumes in the northern rivers were generally within the range of the long-term average flows, except for those in 1997. Table 1 shows annual flow volumes at selected stations on the Peace, Athabasca and Slave rivers for 1997-2001. Also in the table are the 30-year average annual flows for each station. The general pattern throughout much of northern Alberta was very high runoff in 1996 and 1997, with the highest volumes occurring in 1997. This was followed by several years of below to much-below average runoff. This was especially true in the lower Athabasca basin, where record low runoff was recorded.

Table 1. *Annual flow volume (million cubic decametres) at sites on the Peace and Athabasca rivers, 1997-2001 and 30-year average flow volume.* (AENV)

Peace River sites	1997	1998	1999	2000	2001	long term
Hudson Hope	34.9	37.2	35.7	39.3	35.2	36.7
Town of Peace River	74.7	56.0	56.1	60.4	57.6	61.1
Peace Point (Wood Buffalo Park)	96.1	57.4	56.7	61.7	63.0	68.0
Athabasca River sites	**1997**	**1998**	**1999**	**2000**	**2001**	**long term**
Jasper	3.15	2.66	2.93	2.35	2.31	2.72
Town of Athabasca	19.4	10.8	12.8	10.8	10.0	13.7
Below Ft. McMurray	31.9	16.0	14.4	14.2	13.5	20.1
Slave River site	**1997**	**1998**	**1999**	**2000**	**2001**	**long term**
Fitzgerald	155.2	113.7	88.6	89.0	95.4	108.0

Peace-Athabasca Delta

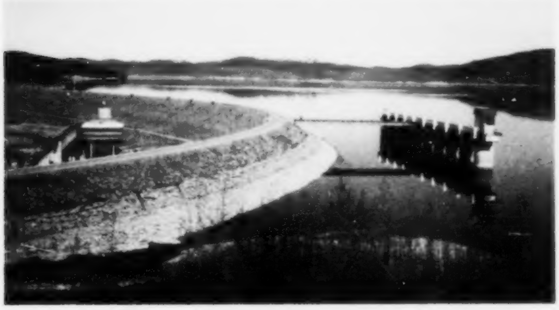
The Peace and Athabasca rivers form a vast delta near Lake Athabasca. The Peace-Athabasca Delta contains marsh, grassland, willows, shallow lakes and rivers. It encompasses 3900 square kilometres, making it one of the largest freshwater deltas in the world. The delta provides homes for large populations of waterfowl, aquatic mammals, bison and 20 species of fish. In 1982, it was designated a wetland of international significance under the Ramsar Convention. As well, Wood Buffalo National Park, which includes about 80% of the delta, was designated an UNESCO World Heritage Site in 1983.

The Peace-Athabasca Delta has four major permanent lakes (Mamawi, Claire, Baril, and Richardson) all with a maximum depth of 3 metres or less. The near shore zone and bays of these lakes are characterized by thick growths of aquatic and emergent vegetation. Freeze-up occurs in late October and ice cover lasts for a minimum of six months. Ice thickness is more than one metre, and all delta lakes are devoid of oxygen and fish by late winter.

> *"It supports waterfowl from all four major continental flyways, and therefore is a globally significant area for these birds".*

The wetlands and grasslands of the Peace-Athabasca Delta provide vital resting and feeding areas for ducks and geese migrating north and south. It supports waterfowl from all four major continental flyways, and therefore is a globally significant area for these birds.

The Peace-Athabasca Delta is an important regional source of fish, supporting productive commercial, domestic, and sport fisheries. A puzzling characteristic of the delta is that in permanent channels and lakes east of Mamawi Lake, walleye are the dominant species, while goldeye are the dominant species in Mamawi and Claire lakes and their associated channels and lakes. The western portion of Lake Athabasca, including the actively expanding portion of the Athabasca Delta, supports a commercial fishery with an annual quota for walleye of 45,400 kg. Important spawning habitat for this walleye population includes Richardson Lake, and bays and channels at the outer edge of the Athabasca River Delta. Mamawi and Claire lakes are critical spawning and feeding habitat for a population of goldeye that winters in the lower Peace River and migrates into the delta in spring. The domestic gill-net fishery for walleye, lake whitefish, northern pike, and goldeye occurs throughout the delta at traditional sites. Sport fishing for walleye and northern pike occurs primarily in the Athabasca River Delta.



Williston Reservoir, W.A.C. Bennett Dam (AENV)

Over the past 25 years the delta has undergone several dry periods, and some of the aquatic habitat is changing to more woody-type vegetation, such as willows. The drying that occurred from 1975-96 was attributed to a lack of flooding from ice jams.

There is some concern that the operation of the Bennett Dam may make the formation of major ice jams more dependent on high tributary inflows. Periodic overland flooding by ice jams is vital to maintain the ponds and lakes that are separated from the open-water channel system. By itself, the flow released from Williston Reservoir cannot cause extensive flooding within the delta. Above-average runoff volumes from the tributaries of the Peace River basin are also necessary to produce flooding.

High spring runoff from major tributaries, such as the Smoky River, provides the driving force needed to create dynamic ice jams in the lower Peace River. Until 1996, spring flows down the Smoky River and other tributaries were too small to cause ice jams.

In 1996 and 1997, above-average runoff from the Athabasca basin and tributaries of the Peace River, in combination with ice jamming triggered flooding in the delta. Such flows also help shape the near-shore habitat on large delta lakes, such as Claire Lake. For example, high summer precipitation in July 1996 produced higher than normal flows in the Peace and Athabasca rivers. At the same time, a structural problem at the W.A.C. Bennett Dam forced the operators to lower Williston Lake. The resulting high flows on the Peace River raised Lake Claire levels and they remained relatively high for almost two years.

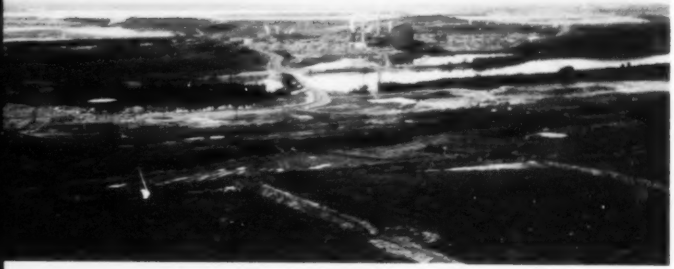
Land Use

Major land uses in the northern basins include human habitation, forestry, agriculture and industrial development.

According to census data from Statistics Canada, the population in the Alberta portion of the northern basins has increased from 246,000 in 1996 to 263,000 in 2001. This represents an increase of nearly 7%. Most of this increase can be attributed to growth in the two major centres, Regional Municipality of Wood Buffalo (Fort McMurray) and Grande Prairie. The population in both of these urban areas has increased by about 18% between 1996 and 2001, making them the fastest growing cities in Alberta. Other areas in the northern basins of Alberta have remained relatively stable or lost population. The population in the two communities along the Slave River in the Northwest Territories, Fort Smith and Fort Resolution, has declined slightly.

Forestry

Forestry is the science, art and practice of managing and using, for human benefit, the natural resources that are associated with forest lands. Seventeen forest companies in the Alberta portion of the study area have Forest Management Agreements (FMA), which dictate the allowable cut of timber. Each company has its own FMA. About 80% of all forestry operations in Alberta occur in its northern basins. In 2002, the annual allowable cut in the province amounted to about 19 million cubic metres of softwoods and hardwoods. There has been very little change in the total allowable cut in Alberta between 1996 and 2001.


Landscape Disturbance, Suncor (AENV)

The Northwest Territories has over 8% of Canada's forest lands (33 million hectares). The Slave River region has been aggressively logged and the Cameron Hills is an area of current forestry activity. Almost none of the forest harvesting currently supports secondary or tertiary industries in the north. Forest regeneration is not a legal requirement, and has been primarily conducted by the territorial government.

Northern forest managers are actively working toward greater capability for forest management and tools to achieve sustainability. As well, traditional knowledge is increasingly being used in planning and decision-making. Challenges include balancing timber uses with other land uses such as the accelerating oil and gas industry and wildlife habitat.

Agriculture

Agricultural operations can affect water quality, mainly through the transport of nutrients, pesticides, sediments and other substances by runoff. About 19% of the land used for agriculture in Alberta is situated in the Alberta portion of the study area. Agricultural land in the Peace-Athabasca basins amounts to about 40,000 km^2. There is relatively little agricultural activity in the Slave River part of the study area.

Agricultural production in the study area of Alberta has increased very slightly since 1996. Cattle are the main types of livestock produced in the area. According to agricultural census data, the number of cattle and the amount of land in crops in the Peace-Athabasca basins have increased very slightly (*Table 2*). Manure is used as a fertilizer and is usually applied by solid spreader. Manure was spread over about 15% more land in these basins in 2001 than in 1996, with the greatest increase in the Peace River basin.

Industry

A major activity on the land is oil and gas production, including seismic exploration. Seismic lines used to have the single largest footprint of any industrial sector. Since late 1996, new regulations in Alberta have reduced the width of seismic lines, and now the amount of land affected is dramatically smaller.

Table 2. *Agriculture in the Peace and Athabasca River basins of Alberta, and for the province of Alberta, 1996 and 2001.* *(Summarized from census of agriculture data, Statistics Canada)*

	No. of Farms Reporting	Acres Farmed, Millions	No. of Cattle, Thousands	Acres in Crops, Millions	Manure Application, Acres
Peace					
1996	7,524	6.888	365	3.728	47,113
2001	6,932	6.984	377	3.908	56,432
Athabasca					
1996	4,685	2.752	414	1.244	96,823
2001	4,280	2.792	448	1.314	109,776
Alberta					
1996	59,007	51.964	5,942	23.590	1,174,700
2001	53,652	52.059	6,615	24.039	1,272,200

A gas or oil well requires about 1.5 ha. Over the past few years, fewer companies have applied to put in wells, but the total land area for this purpose in the northern basins is unknown. As wells cease production, companies are required to shut down the well and reclaim the land according to certain criteria. Companies with a large ratio of unreclaimed, non-producing wells are charged a substantial fee per well to encourage shut down and reclamation. As well, companies are using the same corridors and roads for seismic lines, pipelines, timber extraction and other industrial activity.

Oil sands operations have a major impact on the landscape. The cumulative disturbance to date is over 15,000 hectares or 150 square kilometres (*see Figure 4*). In addition to the mines, large areas are affected by storage of waste sand and soil (tailings) after the oil is extracted. In fact, this effect of oil sands mining far exceeds that of any other form of mineral processing. For example, the tailings pond immediately north of Syncrude's extraction facilities covers over 22 square kilometres. Some estimates suggest that by the year 2023 the overall mining area may be as much as 10 times the area affected to date, potentially exceeding 1,400 square kilometres. Although this area is gradually being reclaimed, opening of new mine areas exceeds the amount of land being reclaimed right now.

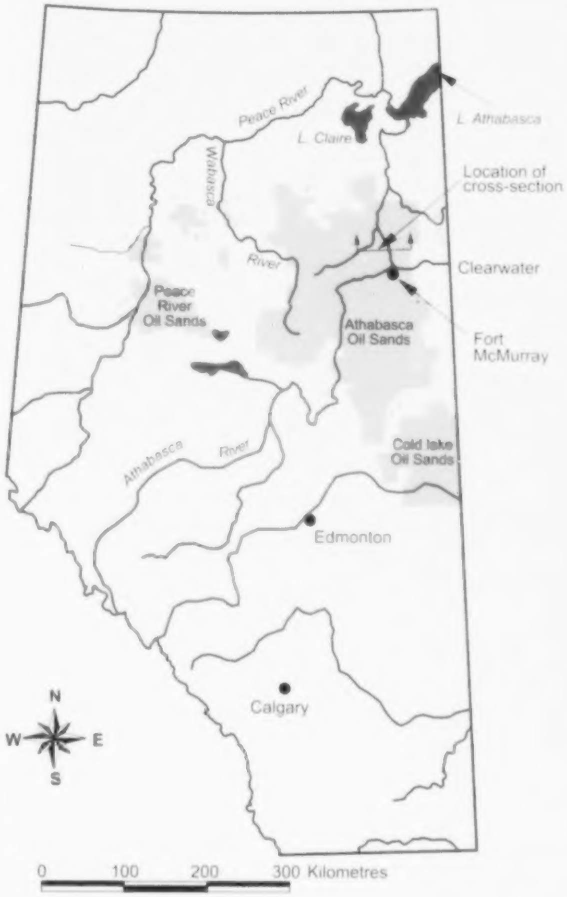


Figure 4. *Location of oil sands deposits in Alberta 2001.* *(Energy and Utilities Board, 2002)*

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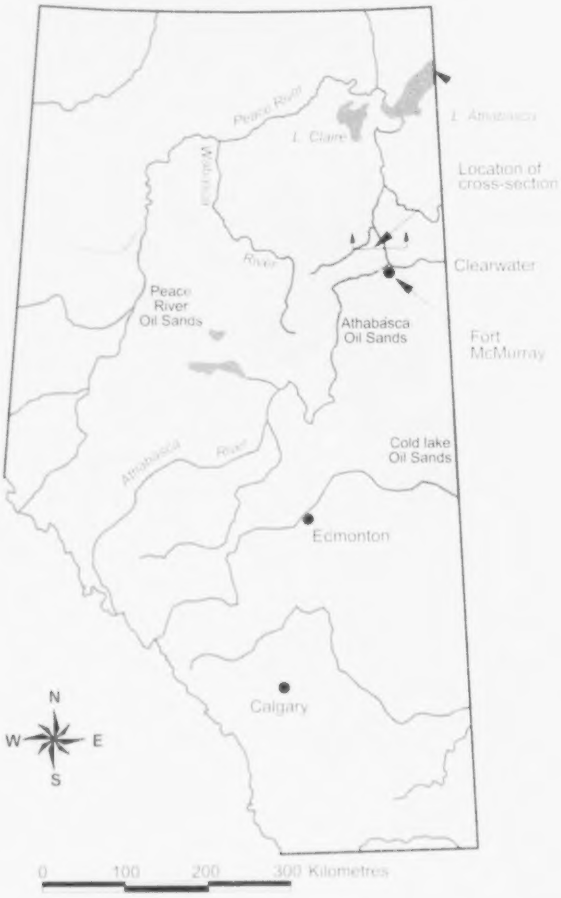


Figure 4. *Location of oil sands deposits in Alberta 2001.* *(Energy and Utilities Board, 2002)*

Water Allocation

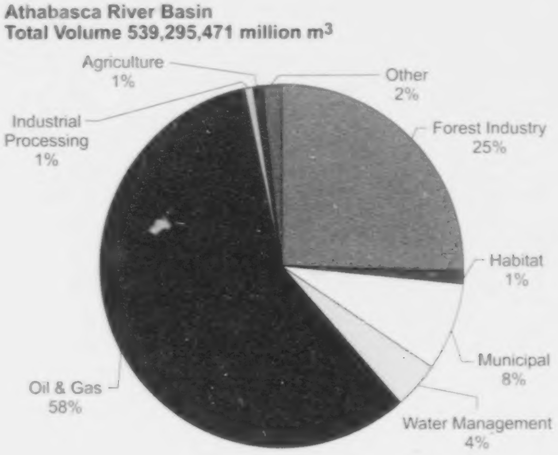
Throughout the northern basins, water is taken from the major rivers, streams, lakes and other surface waters for a variety of purposes. For all water uses, except for households independent of municipal systems, Alberta Environment issues licences that identify the source of supply, location of withdrawal and the quantity of water allowed to be withdrawn (or *allocated*). For many licences, water is withdrawn, used, and returned. Often the quantity returned is less than the quantity withdrawn, and the quality may be different. An example is water that is withdrawn for a municipal supply and returned as treated sewage effluent. For a few uses, such as oilfield injection, the water is lost to the active water cycle.

Because the population in the northern basins is small compared with that of the rest of the province, the amount of water allocated is also relatively small. The total of all current (2002) allocations (surface plus groundwater) in the Peace and Athabasca basins amount to 0.4% and 2.4%, respectively, of the average annual river flows. Figure 5 shows proportions of water allocations for the Peace and Athabasca river basins. More water is licenced for use in the Athabasca River Basin than in the Peace River Basin. A major use in both basins is for pulp and paper and other forest operations (forest industry). The amount of water allocated for the oil and gas industry is much greater in the Athabasca River Basin than in the Peace River Basin. Oil and gas use of water includes oilfield injection, oil and bitumen processing and cooling. Most of the water allocated for fish, wildlife and habitat enhancement in the Peace River Basin is for wetland projects.

The quantity of water licensed for withdrawal from the Slave River is much less than that for the Peace or Athabasca. The main water use on the Slave River is for drinking water treatment.

> *"The amount of water allocated for the oil and gas industry is much greater in the Athabasca River Basin than in the Peace River Basin".*

Fort McMurray Sewage Lagoons (AENV)



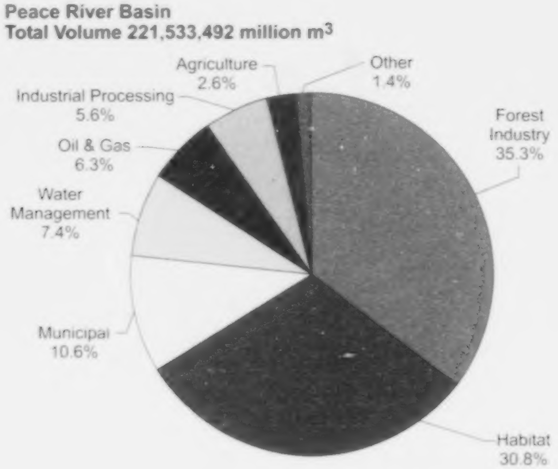


Figure 5. *Surface water allocations for the Peace and Athabasca River basins in Alberta. Total volume is for 2002. (AENV)*

Industrial Development

Northern residents are concerned about industrial development in the Peace and Athabasca river basins, particularly about impacts of industrial wastewater discharges into the major rivers. Industries with the potential to impact surface waters in the basins include pulp and paper mills, oil sands operations and coal mines. No new pulp mills have been built since 1993. Pulp mills currently in operation are listed in Table 3.

Since 1996, twenty-one new oil sands projects have applied for or received approval in the northern basins (*Table 4*). Most of these are located in the large oil sands deposits in the Fort McMurray area. Oil sands operations presently release some refinery wastewater (secondary treatment), sewage effluent (secondary treatment), muskeg and overburden drainage (via sedimentation ponds), mine run-off (via sedimentation ponds), and small amounts of tailings dyke seepage. Future releases may also include treated tailings water and mine depressurization water. The steam-assisted gravity drainage (SAGD) operations have no industrial wastewater discharges to surface water.

Five coalmines are situated near the headwaters of some of the main rivers in the Athabasca River basin. As of 2003, only one is active, three are being reclaimed and one has applied to start up again. One other mine has applied for development in the Peace River drainage basin. Although they have no process wastewater, runoff from the mining-affected land and overburden dumps can affect water quality. Runoff from active mining areas is usually controlled and routed through sedimentation ponds.

Other industries in northern Alberta, such as gas and conventional oil installations, sawmills, oriented strand board plants, and industries outside urban areas, generally have few or no process effluents. Runoff from the larger facilities is normally controlled and given at least primary treatment before release. Environmental issues associated with oil and gas drilling and production were not addressed by NREI.

Table 3. *Pulp and paper mills in the Peace and Athabasca basins. [AENV]*

Pulp Mill	Start-Up	Product	Receiving Water	Nearest Town
Fletcher Challenge	1972	Bleached kraft pulp	Williston Lake	Mackenzie, BC
Finlay Forest Industries	1969	Mech. Pulp, newsprint	Williston Lake	Mackenzie, BC
Louisiana Pacific	1991	BCTMP pulp	No effluent	Chetwynd, BC
Fibreco	1988	BCTMP pulp	Peace R.	Fort St. John, BC
Weyerhaeuser Canada	1973	Bleached kraft pulp	Wapiti R.	Grande Prairie, AB
Daishowa-Marubeni	1990	Bleached kraft pulp	Peace R.	Peace River, AB
Weldwood	1957	Bleached kraft pulp	Athabasca R.	Hinton, AB
Millar Western	1988	BCTMP pulp	Athabasca R.	Whitecourt, AB
Alberta Newsprint	1990	TMP pulp,deinked paper	Athabasca R.	Whitecourt, AB
Slave Lake Pulp	1991	BCTMP pulp	Lesser Slave R.	Slave Lake, AB
Alberta Pacific Forest Industries	1993	Bleached kraft pulp	Athabasca R.	Athabasca/Boyle, AB

Table 4. *Proposed and approved oil sands projects in the municipality of Wood Buffalo 1996-2003.* (AENV)

Company	Project Name	Status	Date Registered or Approved
Suncor	Steepbank	Approved	24-January-1997
Mobil Oil Canada	Kearl Oil Sands Mine	Proposed	29-April-1997
Syncrude	Aurora	Approved	07-April-1998
Shell Canada Ltd.	Muskeg River	Approved	18-June-1999
Suncor	Millennium	Approved	18-November-1999
Syncrude	Mildred Lake Upgrader	Approved	30-June-2000
Pan Canadian	Christina Lake Thermal Project	Approved	11-August-2000
Petro-Canada	MacKay River Oil Sands	Approved	12-September-2000
Petro-Canada	Lewis Steam Assisted Gravity Drainage (SAGD)	Proposed	08-December-2000
Canadian Natural Resources Limited	Horizon Oil Sands	Proposed	04-May-2001
Japan Canada Oil Sands Limited	Hangingstone Steam Assisted Gravity Drainage (SAGD)	Proposed	16-July-2001
Shell Canada Limited	Jackpine Mine	Proposed	03-August-2001
Suncor Energy Inc.	Oil Sands Voyageur	Proposed	15-November-2001
Suncor	Firebag	Approved	09-January-2002
Devon Canada Corporation	Jackfish Steam Assisted Gravity Drainage (SAGD)	Proposed	27-March-2002
Shell Canada Limited	Peace River Complex	Proposed	17-June-2002
Synenco Energy Inc.	Northern Lights Oil Sands	Proposed	29-August-2002
Canadian Natural Resources Limited	Kirby Steam Assisted Gravity Drainage (SAGD)	Appl. Withdraw	09-December-2002
TrueNorth Energy L.P.	Fort Hills Oil Sands	Approved	30-December-2002
Petro-Canada	Meadow Creek Steam Assisted Gravity Drainage (SAGD)	Approved*	11-April-2003
ConocoPhillips Canada	Surmont Commercial Oil Sands	Approved*	22-April-2003
OPTI Canada Inc.	Long Lake *In-situ* Oil Sands, Lease 27	Approved*	28-July-2003

**EUB approval only, EPEA approval pending.*

Oil Sands Tailings Ponds [background] (AENV)

Municipal Development

The majority of people living in the NREI study area obtain drinking water from municipal sources or from First Nations community water systems. Others take their water from wells, creeks, lakes and dugouts, or use bottled water.

All municipalities in Alberta and the Northwest Territories are required to treat their sewage. Table 5 presents municipalities with continuous wastewater discharges in the Peace-Athabasca basins. In Alberta, all wastewater is treated to at least the secondary level, and two communities use tertiary treatment to further reduce nutrients and bacteria. Smaller communities in the Northwest Territories have only primary treatment before discharge to the environment.

There are 132 smaller centres with sewage disposal systems in the Alberta portion of the Peace and Athabasca river basins. Most of these have sewage lagoons, which are usually discharged once per year, although a few discharge twice per year. Most of these release treated sewage effluents to water bodies that are distant from the major rivers in the basins. A few have evaporation lagoons, which do not discharge. Sewage systems that use secondary treatment are also present at the major oil sands plants, Syncrude and Suncor. These facilities discharge treated sewage effluent directly to the Athabasca River.

Another potential source of pollutants is runoff from urban land during rainstorms and snowmelt. Because of the small size of most municipalities in the northern river basins, this would not be a major source.

Table 5. *Major Alberta municipalities with continuous wastewater discharges to northern rivers. n/a = information not available.* (AENV)

Municipality	In Operation Since	Upgraded In	Flow Rate of Effluent Stream, m^3/day	Level of Treatment	Receiving Stream	River Basin
Athabasca	n/a	1982	995	Secondary (lagoons)	Athabasca River	Athabasca
Barrhead	1973	1983	2197	Secondary	Paddle River	Athabasca
Edson	n/a	1980	3402	Secondary	McLeod River	Athabasca
Fort McMurray	n/a	1984	13286	Secondary (complete mixed lagoons)	Athabasca River	Athabasca
Grande Cache	1982	n/a	8111	Secondary	Smoky River	Peace
Grande Prairie	1986	1999-2000	12771	Primary-secondary-tertiary	Wapiti River	Peace
Hinton				Combined with Weldwood pulp mill effluent	Athabasca River	Athabasca
Jasper	n/a	2002	3000 winter, 6500 summer	Primary-secondary-tertiary	Athabasca River	Athabasca
Lac La Biche	n/a	1982	1874	Secondary (aerated lagoons)	Field Lake	Athabasca
Manning	mid-1970s	2002-2003	1009	Secondary (aerated lagoons)	Notikewin River	Peace
Peace River	n/a	1996-1997	3057	Secondary	Peace River	Peace
Peace River Correctional Centre	mid-1970s	n/a	n/a	Secondary	Peace River	Peace
Slave Lake	1980	1992-1993	2869	Secondary (aerated lagoons)	Sawridge Creek	Athabasca
Whitecourt	1977	2001	3737	Secondary	Athabasca River	Athabasca

northern
rivers
ecosystem
initiative

Partnerships and Government Actions

HOW ARE AQUATIC ECOSYSTEMS PROTECTED?

Governments, citizens and organizations are increasingly finding ways to protect the environment. Water is a precious resource. Rivers reflect natural factors and human activities in the basins they drain. To prevent deterioration of aquatic ecosystems, we must reduce contaminants in industrial and municipal effluents, air emissions and those from land-based activities. New knowledge was gained from the *Northern River Basins Study* (NRBS). In part, this resulted in a greater effort to protect aquatic ecosystems. This chapter describes policies, regulations, initiatives and research efforts that are ongoing or new since the end of NRBS.

Lesser Slave River at Bridge North of Mitsue (AENV)

Environmental Management

The total watershed or basin (*Figure 6*) must be considered when attempting to understand and correct the impacts of human activities on rivers and lakes. Preventing deterioration of aquatic ecosystems is not just about controlling industrial effluents, because anything that happens on the land can affect the water and the plants and animals living in it. Many organisations and governments now understand this concept. They are using a holistic view of environmental management – air, water and land must be managed together. Sustainable development is a shared responsibility. Pollution prevention is no longer the jurisdiction of government regulators alone. Increasingly, partnerships that include stakeholders, First Nations, governments and industry are becoming the "way to go". One of the key tools for environmental management is long-term planning, not just for individual industries and their impacts, but also for all activities in the basin.

Mackenzie River Basin

In 1997, the governments of Canada, British Columbia, Alberta, Saskatchewan, the Northwest Territories and Yukon signed the *Mackenzie River Basin Transboundary Waters Master Agreement*. The Agreement commits these governments to maintain the ecological integrity of aquatic ecosystems in the basin while allowing sustainable development and equitable use of the water. It recognizes that activities throughout the basin can affect its water.

Soon after the Agreement was signed, the *Mackenzie River Basin Board* was set up to implement it. The Board's vision is "a healthy and diverse aquatic ecosystem for the benefit of present and future generations." The Board does not regulate resource use, but it can influence regulatory decisions by:

- Informing decision makers;
- Participating in planning, environmental impact assessments or ministerial reviews of sensitive decisions;
- Appearing at hearings to advocate for the ecological integrity of aquatic ecosystems and the wise use of water;
- Providing for effective sharing of information on developments that might affect aquatic ecosystems.

The Board's key responsibilities are: to provide a forum for communication and coordination among all jurisdictions; to make sure that Aboriginal peoples are informed and traditional knowledge is

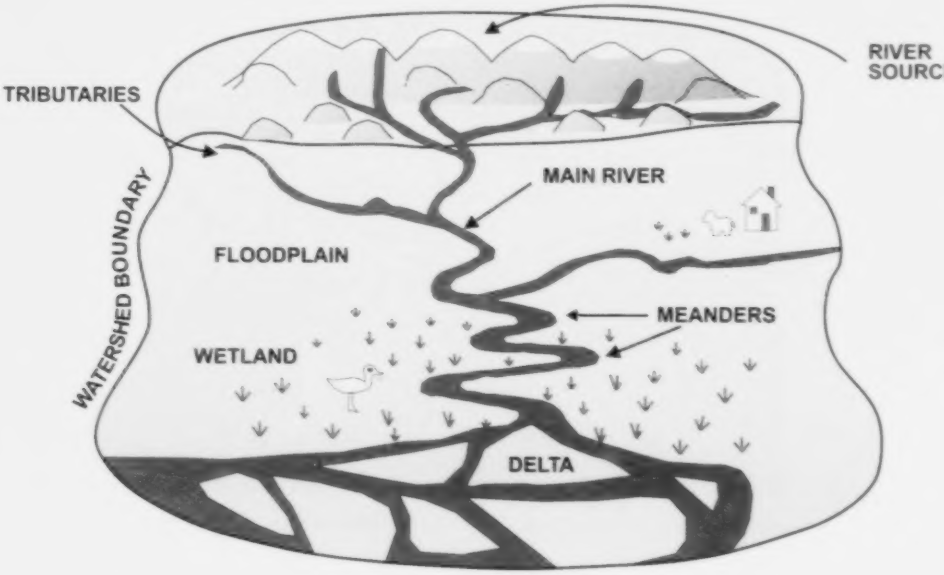


Figure 6. *Diagram of a river watershed. A watershed or basin is all of the land that drains toward the river.* (Environment Canada)

incorporated into decisions; to encourage consistent monitoring programs; and to recommend uniform objectives for the quality and quantity of water.

The Board recently completed *The Mackenzie River Basin State of the Aquatic Ecosystem* report. It used indicators to assess the state of the aquatic environment in the Mackenzie River basin. The report discussed two major issues that impact the whole basin – climate change and contaminants transported into the basin from distant sources. As well, the report used indicators and traditional environmental knowledge to assess whether the Board's water management goals are being met in each of the major sub-basins of the Mackenzie River Basin. These goals are to ensure: human health and safety; healthy, abundant and diverse aquatic species and habitat; water quality improvement; sufficient water quantity; and that in-stream water uses are sustained.

For example, in the Athabasca River Basin, many of the indicators were rated as Favorable or Mixed Signals. But traditional knowledge of human health and safety received an Unfavorable rating because many Aboriginal people in the Fort Chipewyan area perceived that there was a health risk to using the water. For the Peace River Basin, several indicators were rated as Unfavorable, including traditional knowledge of water quality and quantity.

One of the major lakes in the Mackenzie basin is Great Slave Lake. Residents in the area were concerned about the impacts of development on this important resource. As a result, a report was prepared on the status of the lake: *Evaluation of the Vulnerability of the Great Slave Lake Ecosystem.* This report, prepared for Environment Canada as part of the NREI, synthesizes current knowledge about the Great Slave Lake aquatic ecosystem. Its objectives were to understand how it functions, determine its key stressors and assess which components of the ecosystem may be impacted by these stressors. Stressors include fishing, mine drainage, sewage effluent and runoff from Yellowknife, climate change, atmospheric deposition of contaminants, flow regulation by the Bennett Dam and human population growth.

In the report, three distinct areas in the lake were assessed: 1) shore lands, the Slave River delta and inflowing rivers, 2) the Eastern Arm and McLeod Bay, 3) the Western basin. The greatest potential stressors on the shorelands and delta include the dam on the Peace River, commercial fishing and shoreline development. For the pristine Eastern Arm and McLeod Bay, sports fishing may have a significant effect, although little information is available.

View of Great Slave Lake [Hurcomb, GNWT]

For the Western Basin, possible impacts include commercial fishing, although little is known about the impacts of mining, oil and gas or the dam. The report suggests that at present, most of the stressors have little impact on the aquatic ecosystem of Great Slave Lake. But a major lake-wide study of the fish and fisheries should be done, as well as other studies to improve the information base for the lake.

Alberta

Over the past few years, many new initiatives have been developed to manage the environment in Alberta. Most of these involve local or regional stakeholders – people who want to become involved in protecting and managing the water, air and land for future generations.

Water Management

Alberta's *Water Act*, which came into force in 1999, addresses multiple uses for water management. Its purpose is to support and promote the conservation and management of water. The Act upholds existing commitments to water users, while including provisions that protect water quality, provide for fish and other aquatic life, and allow for flexible water management. The Act states that water management is a shared responsibility of all residents in Alberta. Everyone must use water wisely and become involved in water management planning.

Lesser Slave Lake [AENV]

The *Framework for Water Management Planning* outlines the direction for water planning throughout Alberta. Included in the Framework is a *Strategy for the Protection of the Aquatic Environment*. The Strategy reflects the government's commitment to maintaining, restoring and enhancing the aquatic environment throughout Alberta. The integration of water quantity and water quality is a crucial part of planning. Water management plans will be developed through the Framework to provide long-term protection of northern rivers. It applies to rivers, streams, lakes, aquifers and wetlands, and recognizes that no two situations are alike. The Framework is consistent with the document entitled *Alberta's Commitment to Sustainable Resource and Environmental Management*, and uses principles of Integrated Resource Management. As well, it recognizes the linkages between water management planning and planning for other resources. It is critical that water management decision-making is integrated with other planning activities, such as for fish, wildlife, industrial development and land use.

In March 2003, the Alberta government released the draft terms of reference for a water management plan for Lesser Slave Lake and River Basin. For many years, people have had concerns about water management in the basin, both flooding and low water levels. The ultimate purpose of the plan will be to help Alberta Environment make sound water resource decisions. Development of the plan will be a partnership between the government and numerous stakeholder groups. One of the goals is to protect the aquatic environment by managing activities that affect water quality, water quantity, habitat and aquatic species.

A long-term commitment to water quality management is the new water quality performance measure reported annually by Alberta Environment. This is presented in *"Measuring Up,"* part of the Government of Alberta's Annual Report. The performance measure is a water quality index calculated at key river locations throughout the province (*see further information below, under "Monitoring" p. 38*).

In November 2003, the Alberta government released a new approach for managing water. *Water for Life: Alberta's Strategy for Sustainability* is designed to address increasing demands on the province's water supplies, to protect human health and well being, the economy and aquatic ecosystems. Albertans must recognize there are limits to the available water supplies. Citizens, communities, industry and government must share responsibility for water management. It emphasizes a watershed approach to management and decision-making. First actions for the Strategy include reviews of water treatment facilities and industrial uses that remove water from the water cycle.

Regional Strategies

Increasingly, governments are using an integrated approach for managing water and the environment. *Integrated Resource Management* (IRM) can be defined as a way of using and managing the environment and natural resources to achieve sustainable development. Using an IRM approach means that environmental, social and economic issues are considered, while finding ways for all uses to exist together with less conflict.

How we manage or use one resource affects the management or use of other resources in an area. Managing each use or resource by itself is less effective than managing all of them in an integrated way. IRM is based on: cooperation, communication, coordination, consideration of all values, and involvement of those potentially affected. Alberta Environment is working with other government departments, industry, communities, and individual Albertans. Together, they are developing regional strategies as the bridge between provincial policy and local or project planning, and sharing ideas and information on IRM projects.

An Alberta researcher developed a computer program called ALCES to help decision-makers and their

Water for Life: Alberta's Strategy for Sustainability

Alberta is facing pressures on its water resources. Population growth, drought and agricultural and industrial development put stress on the province's water systems. *Water for Life: Alberta's Strategy for Sustainability* envisions Alberta's governments, stakeholders and the public cooperating in a network of community, basin and provincial partnerships – combining knowledge and resources to manage Alberta's water in an efficient and effective manner. This new strategy addresses water management concerns for the future. It is the most comprehensive of its kind in Canada.

Albertans identified three goals for managing water:

- A safe, secure drinking water supply
- Healthy aquatic ecosystems
- Reliable, quality water supplies for a sustainable economy.

To achieve these goals, three core areas were identified:

- Knowledge and research - including scientific knowledge of surface and ground water, understanding emerging issues, and education and awareness to provide the knowledge and tools for action
- Partnerships - includes formalizing partnerships at the provincial, regional and community level and recognizing watershed management and stewardship as shared responsibilities
- Water conservation - focuses on using water effectively and efficiently, and emphasizes the need to improve water use productivity and find effective ways to manage demand and supply issues.

A watershed approach is proposed for the new strategy. This is a focus of efforts within a watershed, taking into consideration both groundwater and surface water. This approach recognizes and plans for the interaction of land, water, plants, animals and people. Focussing efforts at the watershed level gives local communities within that watershed a comprehensive understanding of local management needs and encourages locally led management decisions.

One of the government's first actions is to review and assess all drinking water treatment facilities in the province. This will serve as a basis for future decisions on drinking water standards and infrastructure. Another action is to look at water use by the oil and gas industry, because people were concerned about uses that remove water from the active water cycle.

stakeholders explore how land use practices interact with natural processes. This tool was developed with integrated resource management as the focus and will be used in the development of regional strategies. ALCES can be used as an exploratory tool to identify emerging regional issues and opportunities. It can also be used to examine the potential implications of trends and policy choices under a range of future scenarios. Besides its use in Alberta regional strategies, the federal government in Alberta and the Northwest Territories, Alberta industries, environmental groups and the Universities of Alberta and Calgary are also using ALCES.

In March 2003, draft recommendations were released for a *Northern East Slopes Strategy*. This area includes the upper watersheds of the Athabasca and Smoky rivers. This is the first regional strategy of its kind in Alberta. Guidelines for four themes are described:

- Wise use of the land - appropriate land use;
- Economic stability - sustainable resource development;
- Conservation of biodiversity - protection of native plants and wildlife;
- Air, water and soil conservation.

Oil Sands

Oil sands development in Alberta has been intensifying over the past few years. The unprecedented pace of development in the Athabasca oil sands area presents new challenges for environmental and resource management. These include overlapping needs for access to public land; competition for resources such as forests, wildlife and water; and increased risk of harming environmental quality and human health. In July 1999, regulators and stakeholders completed the *Regional Sustainable Development Strategy for the*

Athabasca Oil Sands Area (RSDS) to manage the cumulative environmental effects of multiple developments in the Athabasca oil sands area. The 72 issues identified by the Strategy were grouped into 14 themes, which were further separated into three categories based on information gaps and urgency. Work has begun on 'Category A' themes, which include:

- Sustainable ecosystems;
- Cumulative impacts on wildlife;
- Biodiversity;
- Effects of trace metals in air emissions on human health, wildlife and vegetation; and
- Bioaccumulation of heavy metals.

Based on further consultation with aboriginal communities, a surface water theme (water quality/quantity & fisheries) was also moved forward in the timeline. Additional information on the *Regional Sustainable Development Strategy for the Athabasca Oil Sands Area* is available on the Internet.

Albian Oil Sands Construction Site (AENV)

The stakeholder group involved in the design of RSDS has since become an official association, the *Cumulative Environmental Management Association* (CEMA). CEMA is intended to seek consensus-based solutions to environmental management issues in the Athabasca Oil sands area. It is developing management recommendations on environmental capacity guidelines, environmental management objectives, and management systems. Once CEMA approves a set of management recommendations, these will be forwarded to the appropriate agency or organization for implementation. Such agencies could include regulators (e.g., Alberta Environment or the Energy and Utilities Board), industry, other monitoring or research organizations (for example, the Wood Buffalo Environmental Association or the Regional Aquatics Monitoring Program), and other organizations. CEMA does not intend to implement its own management recommendations, conduct long-term monitoring or carry out research projects.

CEMA has formed five working groups to begin resolution of the RSDS 'Category A' themes and surface water issues. The Sustainable Ecosystems Working Group deals mainly with terrestrial issues. The Trace Metals and Air Contaminants Working Group and the NO_X/SO_2 Management Working Group are addressing the effects of air emissions and acidic deposition on ecosystems (*see p. 23*). Tasks of the Surface Water Working Group include determining instream flow needs for the Athabasca River, defining indicator criteria for the Muskeg River and developing a management system for water quality in the lower Athabasca River. The final Working Group is addressing reclamation. Many of the projects under these working groups will be completed in 2003 and 2004. A report on the CEMA schedule and the timing of oil sands development was issued in late 2002. The report lists each industrial project in the oil sands area and expected completion dates. Information on total emissions, land disturbance and water use is also in the report.

Peace-Athabasca Delta

People have been concerned about the ecological integrity of the Peace-Athabasca Delta since the W.A.C. Bennett Dam was completed in 1967. The reservoir behind the dam, called Williston Lake, took five years to fill. Changes in water flow had an effect over one thousand kilometres downstream at the Peace-Athabasca Delta. The annual alpine runoff, which contributed to the periodic flooding of vast marshlands of the Delta, was held behind the dam. The lower water levels caused much of the marshland to dry up, reducing the nesting habitat of thousands of migratory waterfowl. The muskrat harvest dropped from 38,000 pelts to less than 2,000 in the four years after the dam began operation.

Weirs to retain water in parts of the wetlands reduced the impact, but habitat for tens of thousands of birds and mammals had been altered.

Eventually, governments and BC Hydro began a series of technical studies to understand the environmental and social impacts of dam operation on the Delta. Structures were built to maintain water levels in Lake Athabasca. Although these were reasonably successful, the Delta continued to dry.

Another series of technical studies were done in conjunction with NRBS. After these were completed in the mid-1990s, the governments involved began discussions to develop an ecosystem management plan for the Delta. A draft plan was prepared in 2000 and presented to the main stakeholders. But little has been done since then. New information collected during NREI, and by BC Hydro, should help with future planning for this important area.

W.A.C. Bennett Dam (AENV)

Air Issues Management

Air quality is important to northerners. Not only does poor air quality affect human health, it can also harm rivers and lakes. The *Clean Air Strategic Alliance* (CASA) is a stakeholder partnership that has been given shared responsibility by its members, including the Alberta and federal governments, for strategic air quality planning, organizing, and coordinating resources, and evaluation of results through a collaborative process. CASA's vision is to make sure that the air will be odourless, tasteless, look clear and have no measurable short- or long-term harmful effects on people, animals or the environment.

The governments recognize the value Albertans place on protecting the environment and public health. CASA was asked to lead development of a new approach to managing air emissions from the province's electricity sector. The new approach will ensure that an appropriate balance between environmental quality and economic growth is achieved. CASA and the Alberta government conduct passive and continuous air quality monitoring in regions where local stakeholders have joined together to work on air quality issues for their region. An airshed is an area where emissions cause deposition of air pollutants to a region. There are currently six airsheds in Alberta. In the study area, they are in the Wood Buffalo, Grande Prairie and Jasper-Hinton areas.

CEMA formed the NO_X/SO_2 Management Working Group at its inaugural meeting in June 2000. The Working Group is charged with "reviewing the relevant science and developing a management plan (system) for NO_X (oxides of nitrogen) and SO_2 (sulphur dioxide) emissions as they relate to acidification." They will also establish environmental capacity guidelines, environmental management objectives and a management system and plan for ground-level ozone.

The Working Group objective for NO_X and SO_2 emissions, as they relate to acidification, is to review the relevant science and develop a management system for current and projected emissions levels, receptor sensitivities and appropriate levels of protection. As emissions relate to ozone, the objective is to design a management system to address ground-level ozone and its effects on vegetation and human health.

Northwest Territories

Resource-based development is increasing in the Northwest Territories (NWT). Although many northerners welcome renewed economic growth, the issues raised for environmental and resource management are also widely recognized. Resource development and economic activity can result in significant social, cultural and environmental changes. As exploration and development intensify, environmental changes will often be the result of the combined impacts of multiple projects and activities. The prevention, assessment and management of harmful cumulative effects are therefore important priorities for residents of the NWT, and major challenges for decision makers within the NWT's rapidly evolving institutions.

The NWT *Cumulative Effects Assessment and Management* (CEAM) Steering Committee was formed to deal with these issues. The Committee is composed of members from First Nations groups, territorial and federal governments, industries and the Mackenzie Valley Environmental Impact Review Board. The Steering Committee, in consultation with a range of interested parties, developed the CEAM Strategy and Framework and a Blueprint for Implementation. The Framework encourages partners to:

- Protect ecological integrity,
- Build sustainable communities (including social and economic dimensions) and
- Promote responsible economic development within a context of sound environmental management.

Looking Across Great Slave Lake (Macintosh, GNWT)

Wildlife and Fish Management

The *Alberta Conservation Association* (ACA), which was set up in 1997, is a non-profit, non-government association working collaboratively to conserve, protect and enhance Alberta's wildlife, fisheries and habitat. Annually, the organization focuses several million dollars towards conservation efforts, delivering a wide variety of projects, programs and services across the province. Projects include:

- Research and data collection;
- Monitoring, analysis and evaluation;
- Facilitation of a variety of projects;
- Industry information; and
- Public education.

The ACA receives funding from a variety of Alberta conservationists, including significant contributions from hunters and anglers and a growing group of corporate partners. In 2001-2002, the ACA received $9.8 million for its projects, most of which came from hunting and angling licences. The organization works collaboratively with Alberta Sustainable Resource Development to enhance and protect wildlife and fish populations.

The *Fish Conservation Strategy for Alberta 2000-2005* is a guide for the management of fish resources in Alberta. Conservation of fish populations includes maintaining habitat, regulating the harvest so that only surplus fish are taken and allocating fisheries use to achieve a range of benefits. These goals often mean balancing recreational, subsistence and commercial fishing with the need to conserve fish stocks. Protecting fish habitat is particularly important in Alberta, because fish-producing waters are limited and demand for fishing is increasing. The Strategy will be reviewed in 2004 and updated if necessary. Because Alberta shares fisheries management with the federal government, the *Fish Conservation Strategy* provides a key benchmark for both levels of government.

In the Northwest Territories, wildlife is managed and protected by boards with both First Nations and Territorial government members. As well, a *Protected Areas Strategy* is designed to protect specific areas of land with natural and cultural values. The Strategy lays out a process designed to protect ecosystems, biodiversity and traditional harvesting areas with current legislation. At present, there are five migratory bird sanctuaries, two wildlife sanctuaries and other areas that protect wildlife. As well, a few years ago the East Arm of Great Slave Lake was proposed as a National Park. Regional Plans of Actions are being developed under the *Cumulative Effects Assessment and Management Framework and Strategy*. One of the goals of these plans is to protect wildlife and their habitat.

Ducks Unlimited Canada is a non-profit organization set up in 1938 to protect waterfowl populations and their habitat. Ducks Unlimited conserves, restores and manages wetlands and associated habitats for North America's waterfowl. These habitats also benefit other wildlife and people. Three major programs are conducted: habitat conservation, research and education. The purpose of each program is directed to putting more habitat in place for waterfowl and wildlife. As a result, Ducks Unlimited has secured and enhanced nearly 19 million acres of habitat across the country.

In 2001, the *North American Waterfowl Management Plan* produced a document entitled "*Alberta's Wetlands: A Law and Policy Guide.*" The document contains information on the various laws and policies that may affect the condition or existence of Alberta's wetlands. It focuses on the needs of wetland managers – anyone concerned with or about wetlands, including government agencies, conservation organizations, private landowners and concerned citizens.

Environment Canada has initiated the *Western Boreal Conservation Initiative* to facilitate conservation and protection of western boreal forest ecosystems and their biodiversity. This multi-partnered program supports sustainable development of natural resources and provides a foundation for a future national initiative. The first phase is scheduled for 2003-2008 and will focus on biodiversity conservation issues in the boreal forest. It will include habitat loss and fragmentation, species at risk, water, integrated resource management and climate change.

Canada's new *Species at Risk Act* (SARA) aims to prevent endangered or threatened wildlife from becoming extinct or lost from the wild, and to help these species recover. The Act supports other environmental efforts, and is based on cooperation among governments, consultation with people affected by a SARA action, stewardship activities and ongoing species review. SARA provides a way for the government to take immediate action to protect wildlife in imminent danger.

Pollution Prevention

Preventing pollution is the ultimate goal of everyone in the northern river basins, including governments, industries, municipalities, First Nations and other northern residents. The principles of pollution prevention and continuous improvement guide regulatory activities to protect the environment. A number of acts, regulations, policies, guidelines and agreements have been initiated in the past few years. Many of these build upon or replace such legislation and policies already in place.

Pollution

Pollution is the contribution of substances from human activities that make the environment less suitable for certain uses.

For example, pollution of water may cause changes in physical, chemical or biological characteristics that could harm beneficial uses of the water, including plants and animals living in it.

Canada

Canadian environmental laws and policies pertain to the entire country. They allow us to deal with substances that are transported by air or in rivers that cross provincial and international boundaries.

Toxic Substances

The *Canadian Environmental Protection Act* (CEPA) was revised in 1999. Its goal is to protect the environment and the health of Canadians from toxic substances and other pollutants. The pollution prevention thrust of CEPA will help Canada contribute to sustainable development and make Canadian industry more competitive internationally. Because science is constantly evolving, the Act will be reviewed by Parliament every seven years. The new CEPA will make pollution prevention a national goal, and includes:

- Powers to require pollution prevention planning for substances declared toxic under CEPA,
- A national information clearinghouse through which industry can share knowledge and technology on pollution prevention activities, and
- An awards program to recognize pollution prevention efforts.

In January 1998, all jurisdictions of the Canadian Council of Ministers of the Environment (CCME), including Alberta and the Northwest Territories, signed the *Policy for the Management of Toxic Substances*. The policy provides a coordinated approach for priority setting and management of toxic substances. Many of these materials can move across political boundaries, including international ones. A national policy will give us a strong negotiating position abroad in dealing with pollutants transported by air and a better international situation for industry. As well, data from across the country can be assembled to develop regional strategies for managing toxic substances.

The Canadian Council of Ministers of the Environment has been developing *Canada-Wide Standards* (CWS) for a variety of toxic or health-related substances. The Ministers work together to address key environmental protection and health risk issues that require common environmental standards across the country. A CWS is a targeted reduction of quantities of toxic materials in sources such as industrial discharges, usually by a specific date. For example, the Ministers have agreed to develop a CWS for mercury from coal-fired power generating stations by 2005. This is the single largest source of mercury in Canada. All power plants will be expected to meet the standard by 2010.

CCME

The Canadian Council of Ministers of the Environment is the major intergovernmental forum in Canada for joint action on environmental issues of national and international concern.

It is made up of environment ministers from the federal, provincial and territorial governments.

It proposes consistent environmental guidelines to achieve a high level of environmental quality across the country.

By implementing the CWS, governments will be able to use the most effective and efficient measures to protect the environment. Proposed Standards presented to the Ministers generally contain:

- A numeric limit (for example, in air, products or discharges);
- A timetable for attainment; and
- A framework for monitoring progress and reporting to the public.

Each standard is accompanied by a list of preliminary actions to attain the standard. The following substances have Canada-Wide Standards:

- Fine particulate matter
- Ground-level ozone
- Benzene
- Mercury from incineration and base metal smelting
- Dioxins and furans for waste incinerators and pulp and paper boilers burning salt-laden wood
- Petroleum hydrocarbons in soil; and
- Mercury in lamps and dental amalgam waste.

Currently, additional CWS are under development for:

- Dioxins and furans emissions from iron sintering, steel manufacturing, and conical waste burners; and
- Mercury emissions from electric power generation.

Details and accompanying documents on Canada-Wide Standards are posted on the CCME Internet site.

Air Pollution

The transport of contaminants in the air is a concern, because many actual sources are poorly understood. Most of these contaminants are eventually deposited on the Earth's surface, where they can enter water bodies. Canada continues to address transboundary air pollutants through: commitments to the 1991 *Canada-US Air Quality Agreement*; the *North American Agreement on Environmental Cooperation*; and the *Convention on Long-Range Transboundary Air Pollution* (CLRTAP). Canada has been strongly committed to CLRTAP from its beginning. The Executive Body of CLRTAP adopted the *Protocol to Abate Acidification, Eutrophication and Ground-level Ozone* in Gothenburg (Sweden) on November 30, 1999. The Protocol sets emission ceilings for 2010 for four pollutants: sulphur, nitrogen oxides (NO_X), volatile organic compounds (VOCs) and ammonia. These ceilings were negotiated on the basis of scientific assessments of pollution effects and the technology to reduce them. Countries whose emissions have a more severe environmental or health impact and whose emissions are relatively cheap to reduce will have to make the biggest cuts. Once the Protocol is fully implemented, Europe's sulphur emissions should be cut by at least 63%, its NO_X emissions by 41%, its VOC emissions by 40% and its ammonia emissions by 17% compared with those in 1990.

A number of large-scale international actions are underway to address mercury emissions:

- An *Action Plan for Mercury Reduction* is being developed through the North *American Agreement for Environmental Cooperation*, which is the environmental side agreement for the *North American Free Trade Agreement* (NAFTA). It was signed by Canada, the United States and Mexico to address regional environmental concerns;
- A *Heavy Metals Protocol* to control releases of heavy metals, including mercury, in Europe and North America, has been completed and is under way.

At the April 2001 meeting of the Canadian Council of Ministers of the Environment, the council approved a strategy to accelerate the phase-out of CFCs (chlorofluorocarbons) and halons, and to dispose of surplus stocks of these chemicals. This action will further guard against destruction of the ozone layer. The ozone layer reduces the amount of harmful ultraviolet radiation reaching earth.

Persistent Organic Pollutants

Persistent organic pollutants (POPs) are chemical substances that stay in the environment, bioaccumulate through the food web, and may cause harm to human health and the environment. There is evidence of long-range transport of these substances to regions where they have never been used or produced. As a result, they are a threat to the environment of the whole globe. The international community called for urgent global actions to reduce and eliminate releases of these chemicals.

In May 2001, 127 countries, including Canada, formally adopted a global treaty banning 12 highly toxic chemicals. The *Stockholm Convention on Persistent Organic Pollutants* is aimed at eventually eliminating all hazardous chemicals, but lists 12 for priority action. These 12, widely known as "the dirty dozen", include PCBs and dioxins and furans as well as DDT and other pesticides used in industry or created by improper waste disposal. Production and use of most of the chemicals will be banned as soon as the treaty takes effect, following ratification by at least 50 countries. Canada was the first country to ratify the treaty, and in 2002 it was sent to the Congress of the United States for consent and ratification.

The Convention obligates all participating countries to take measures to eliminate or restrict the production, use and trade of intentionally produced POPs. As well, they must develop action plans to address the release of byproduct POPs, and address the safe handling and disposal of POPs stockpiles and wastes.

The Dirty Dozen

The "dirty dozen" include aldrin, chlordane, DDT, dieldrin, dioxins, endrin, furans, heptachlor, hexachlorobenzene, mirex, polychlorinated biphenyls (PCBs), and toxaphene.

These chemicals fall into three categories: pesticides, industrial chemicals, and unintended by-products of combustion and industrial processes.

Greenhouse Gases

Perhaps the most important environmental threat these days is climate change. The "greenhouse effect" is the rise in temperature that the Earth experiences because certain gases in the atmosphere (carbon dioxide, nitrous oxides, water vapor and methane) trap energy from the sun. Without these gases, heat would escape back into space and Earth's average temperature would be much colder. When fossil fuels are burned, large quantities of carbon dioxide are released. Over the past 50 years, levels of carbon dioxide in the atmosphere have increased substantially. People also affect the climate by clearing land for forestry, agriculture and cities. This changes the way the Earth's surface reflects sunlight and reduces its capacity to absorb greenhouse gases.

The *Kyoto Protocol* is a first step toward reducing these gas emissions. The Protocol commits 55 developed countries to cut their emissions of greenhouse gases to levels that are five percent below 1990 levels, by 2008-2012. This would represent 55% of the total world emissions for 1990. It also suggests that rich countries should help poor countries by providing financial and technological assistance to develop in a sustainable way. Although Canada ratified this accord, many countries, including the United States, have not. In ratifying the accord, Canada has made climate change a national priority.

Pulp Mill Effluent

The federal government has legislation to protect rivers from the harmful effects of pulp mill effluents. In May 1992, it passed amendments to the *Fisheries Act Pulp and Paper Effluent Regulations*. These amendments require pulp and paper mills in Canada to conduct *Environmental Effects Monitoring* (EEM). Under the EEM program, mills and off-site treatment facilities that discharge to aquatic environments must conduct regular monitoring studies on their receiving waters to determine if fish, fish habitat and the use of fisheries resources are adequately protected. A number of possible alternatives for further actions may be required depending upon the results of these studies. These alternatives include:

- Development of action plans to reduce impacts,
- Regulatory action (national or site-specific),
- Revision of the EEM requirements, and
- Further research and development programs conducted jointly by industry and government.

Municipal Effluent

Federal, provincial and territorial governments are working together to develop a Canada-wide strategy for municipal wastewater effluent. This initiative will assist in the use of science and research, legislation and environmental risk management modelling to help communities manage their sewage better and protect the environment.

Millar Western Pulp Mill on the McLeod/Athabasca River Confluence near Whitecourt (AENV)

Alberta

Several activities in Alberta that could produce pollutants are regulated under the *Alberta Environmental Protection and Enhancement Act* (EPEA). These include major projects such as oil sands operations, pulp mills and municipal water and waste treatment plants, and smaller activities such as waste disposal; recycling of lubricating oil, tires and beverage containers; use of pesticides; and restoration of contaminated sites. Before a development is allowed to release pollutants into the air or water, a proposal is submitted to Alberta Environment. Major developments that could harm the environment may have to go through an environmental assessment. The Environmental Assessment Process provides a formal means of reviewing projects to assess their potential impact on the environment. The process allows for full public participation and ensures that economic development occurs in an environmentally responsible manner. The purpose of the Environmental Assessment Process is to:

- Support the goals of environmental protection and sustainable development,
- Integrate environmental protection and economic decision-making at the earliest stages of planning,
- Predict the environmental, social, economic and cultural consequences of a proposed activity,
- Assess plans to mitigate any resulting adverse impacts, and
- Involve the public, proponents and government departments and agencies in the review of proposed activities.

Approvals under EPEA are considered "living documents," and address performance, monitoring and reporting requirements. A living document is one that allows the industry time to plan in an orderly way, yet allows changes in effluent limits if deemed necessary. Examples of such living documents are the approvals issued to the Weyerhaeuser Canada mill in Grande Prairie in 1997 and to the Daishowa-Marubeni International Ltd. mill in Peace River in 1998.

Projects related to energy, such as oil sands, and utilities, such as power plants, need approval from the *Energy and Utilities Board* (EUB). The EUB regulates the safe, responsible, and efficient development of Alberta's energy resources – oil, natural gas, oil sands, coal, and electrical energy – and the pipelines and transmission lines to move the resources to market. The main focus of an EUB decision is whether the project is in the public interest. After the EUB approves a project, then it must be approved under EPEA.

EUB hearings are held when the EUB receives an objection from a person who may be directly and adversely affected by a proposed project. A EUB hearing is a formal and quasi-judicial proceeding. It provides a level playing field for all participants – each has the opportunity to know and question the positions of others. This allows the Board to make a fully informed decision.

Releases to surface water from industries and municipalities require site-specific approvals or licences. These approvals address the conservation and protection of water resources as an underlying principle. Approval or release limits regulate the amount of substances that can be legally released into the environment.

Approval Limits

Approval limits are the amounts or concentrations of specific substances that industries or municipalities are allowed to discharge in their wastewater.

For example, for the indicator BOD, a sewage treatment plant is allowed to discharge a monthly average of 25 mg/L and a pulp mill 3 kg per day per air-dried metric tonne of pulp produced.

In 2000, Alberta Environment issued the document *Industrial Release Limits Policy*, which replaced a similar document from 1995. The revised document contains the same principles as the 1995 version, and further extends the policy for setting the approval limits for protecting air and soil. The intent of the Policy is to provide an overview of the principles and procedures used by Alberta Environment staff when developing industrial release limits. These limits are required to ensure that:

- The environment and human health are protected;
- The most appropriate pollution control technologies are adopted;
- Continuous improvement is sought.

Two parallel investigations are conducted before approvals are issued: 1) determine the release limits required to maintain air, water, and soil quality, and 2) determine the release limits based on the capability of the most effective pollution prevention and control technologies. The results of these two investigations are compared and the more stringent result is applied as the release limit.

This means that even if ambient air, water and soil quality can be maintained with less effective pollution control technologies, the company will still have to adopt the most effective technology.

In 2000, Alberta released its *Compliance Assurance Principles*. Compliance assurance activities make sure that all regulated activities, including industries and municipalities, comply with environmental legislation. These Principles include education, prevention and enforcement to achieve compliance.

Alberta Environment has been restructured to be a more "policy focussed" department. This restructuring involved setting up Branches that focus on standard setting, education/partnerships and accountability. The new focus will place greater emphasis on collaborative relationships with stakeholders and flexible regulatory and non-regulatory tools to achieve environmental and sustainability objectives. The new approach is reflected in Alberta's *Water Strategy*. It is being adopted in various other departmental initiatives including the Compliance Assurance Principles.

The Alberta *Codes of Practice* are like approvals, but are developed for activities with minor emissions. There are many small operations that fall into this category. The Alberta government believes that this is the most effective way to regulate these types of activities.

Alberta Environment is preparing a *Monitoring and Reporting Directive*, which will outline the acceptable monitoring practices and reporting formats for those air and wastewater monitoring requirements specified in industrial and municipal approvals issued under the *Environmental Protection and Enhancement Act*. This new Directive will cover methods of sampling, analysis, reporting and data quality assurance. It will also apply to any other monitoring by partnership organizations that submit data to Alberta Environment. The main goal of the Directive is to make sure that all data submitted are consistent and of high quality. Work on the Directive is on going.

Alberta Environment has developed a new program, the *Leaders Environmental Approval Document* (LEAD), and will pilot test it at selected industries. It has potential to benefit both industries and the environment. Under this program, Alberta Environment will amend the facility's approval to allow more reporting flexibility in exchange for enhanced environmental performance.

LEAD facilities will be expected to display continuous improvement in environmental performance. At the end of the pilot testing, a decision will be made on full implementation of the LEAD program.

Pulp Mills

Major improvements in plant process and wastewater treatment in the 1990s have generally resulted in reduced amounts of pollutants entering rivers from pulp mills. Mills in Alberta use the best technologies available and are among the best performing mills in the world.

Contaminants of concern in pulp mill discharges may include suspended solids, colour, biochemical oxygen demand (BOD), nutrients, some metals, resin acids and chlorinated organics (including dioxins and furans).

Pulp mills have used two main approaches to reduce pollution of aquatic ecosystems. One approach involves preventing pollutants from being formed. At bleached kraft pulp mills this has been accomplished through the implementation of two new technologies called elemental chlorine-free bleaching and oxygen delignification (*Figure 7*). Both of these changes prevent or reduce formation of dioxins and furans, and other chlorinated contaminants. Another approach for reducing pollution is to treat wastes before they are discharged. For example, all Alberta pulp mills use biological treatment technology. This process uses bacteria to break down wastes. Weldwood of Canada (at Hinton) upgraded their process technology in the late 1980s, and in 1993 switched to elemental chlorine-free bleaching to improve the environmental performance of the mill. Weldwood's renewed provincial approval, issued in 1998, also reduced the loading limits for both colour and chlorinated organics.

Daishowa-Marubeni International Ltd. at Peace River also received a renewed approval in 1998 that set more stringent limits for colour and chlorinated organics. The mill was required under the approval to convert to elemental chlorine-free bleaching, which is now in place.

Weyerhaeuser's Grande Prairie pulp mill, has upgraded to include both chlorine-free bleaching and oxygen delignification. Alberta Environment has set increasingly stringent limits on colour in effluent from the Weyerhaeuser pulp mill, which goes into the Wapiti River. Colour discharge limits will be decreased by 87% between 1990 and 2007. This mill has reduced colour in the effluent by 26% and certain chlorinated organic compounds (measured as AOX – adsorbable organic halides) by 33% over the past three years.

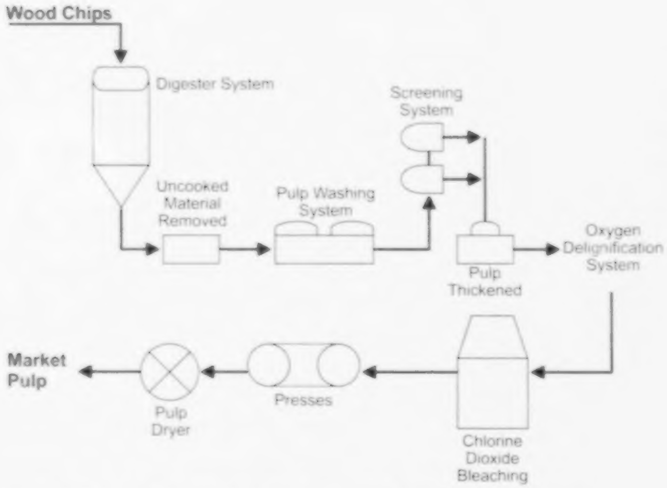


Figure 7. *Pulp production process for a kraft mill. (AENV)*

The Alberta Pacific mill near Boyle already has more stringent limits on its discharges than other mills. Limits for the remaining pulp mills will be reviewed when their approvals are renewed over the next decade.

One of the concerns in pulp mill effluent is a high amount of organic material, which can reduce the amount of oxygen in the river. This could harm fish and other aquatic life. The oxygen-depleting material is measured as Biochemical Oxygen Demand (BOD). Nutrients such as phosphorus are added to pulp mill wastewater treatment systems to improve microbial breakdown of organic wastes and reduce the toxicity of the wastewater.

The goal is to reduce the BOD of the wastewater discharged and thereby maintain adequate dissolved oxygen levels in the rivers. To ensure the best balance between nutrient addition and adequate dissolved oxygen levels, Alberta Environment has requested in their approvals that companies develop plans to reduce nutrients, BOD and toxicity in their effluents. Submission of the plans is required at staged intervals over the term of an approval to allow regular review of new technology and pollution control options.

Oil Sands Operations

Water contaminants of potential concern in present and expected oil sands effluents include residual hydrocarbons (e.g., naphthenic acids, PAHs), ammonia, salts, and some metals. These substances are of concern because they are potentially toxic and may taint fish. Thus, traditional domestic use of fish could be impacted. As well, air emissions from oil sands operations may be harmful because the airborne deposition of compounds derived from sulphur dioxide (SO_2) or nitrogen oxides (NO_X) can acidify soil and water and damage vegetation. Trace metals in air are also a concern.

A new recovery process has been implemented for several of the present and proposed oil sands operations. This is called Steam Assisted Gravity Drainage. Two wells are drilled into an oil sands formation, and steam is injected above the producing zone. The heat melts the thick oil, which then flows freely to the horizontal production well below. Then the oil can be pumped out. This process has no effluent and uses saline groundwater for steam.

Oil sands tailings ponds currently cover large areas near the oil sands plants, and contain large volumes of contaminated water. There are presently no tailings pond discharges, but eventually there may be. The oil sands industry has begun considerable research and development to reduce the toxicity and volumes of these conventional tailings ponds. Applied research into a variety of treatment alternatives, such as consolidated tailings, wetland treatments and end-pit lake development is underway. One possible concept is for wastewater to seep from solidifying tailings deposits, trickle through constructed and natural wetlands into end pit lakes, then flow off-site eventually to the Athabasca River.

The Alberta *Environmental Protection and Enhancement Act* requires oil sands operators to reclaim disturbed land to a capability that will support the intended end land uses on the reclaimed area. The *Guideline for Wetland Establishment on Reclaimed Oil Sands Leases* (March 2000) provides an approach to the development of wetlands on reclaimed landscapes in the oil sands region. It was developed by the Oil Sands Wetlands Working Group, which had representation from government, industry, consulting firms, universities and aboriginal communities. The design and requirements of wetlands must be an integral part of mine planning and design, as well as mine closure planning. The Guideline will also assist the public in understanding the function and value of wetlands and to participate in the establishment of wetlands on reclaimed landscapes. The Guideline is available on the Internet.

Oil sands operations are required through their EPEA approvals to report yearly on initiatives to minimize and reduce atmospheric emissions from their mobile equipment and plant sources. Four oil sands mining projects are currently in operation:

Oil Sands

Oil sands are grains of sand surrounded by a film of water and clay, with bitumen (petroleum) filling the pore spaces between the sand grains. Originally, the sands were deposited as the delta of an ancient river, which flowed into a primeval sea located in what is now northern Alberta. The oil moved up into shallow parts of the sands. Then, bacteria removed parts of the oil and left behind thick, sticky materials known as bitumen, asphalt or tar. Today bitumen can be found seeping from the sand along sun-warmed riverbanks

Albian Oil Sands Plant and Recycle Pond (AENV)

Suncor, Syncrude Mildred Lake, Syncrude Aurora North and Albian Muskeg River. Of these, Suncor and Syncrude are the dominant sources of total SO_2 emissions. A Flue Gas Desulphurization unit was installed at Suncor in 1995 and their upgrader plant was improved. As a result, sulphur dioxide emissions were reduced by over 75% from their previous annual average of 230 tonnes per day. Syncude's emissions were trending downwards during the mid 1990s, but in the past couple of years there was a small increase due to plant modifications and expansions. In August 2003, Syncrude submitted an application to install an additional Flue Gas Desulphurization unit, which will reduce their SO_2 emissions by over 50 per cent from their currently approved levels of 245 tonnes per day.

Pre-1996 Seismic Lines in Alberta (ASRD)

Seismic Lines and Conventional Oil and Gas

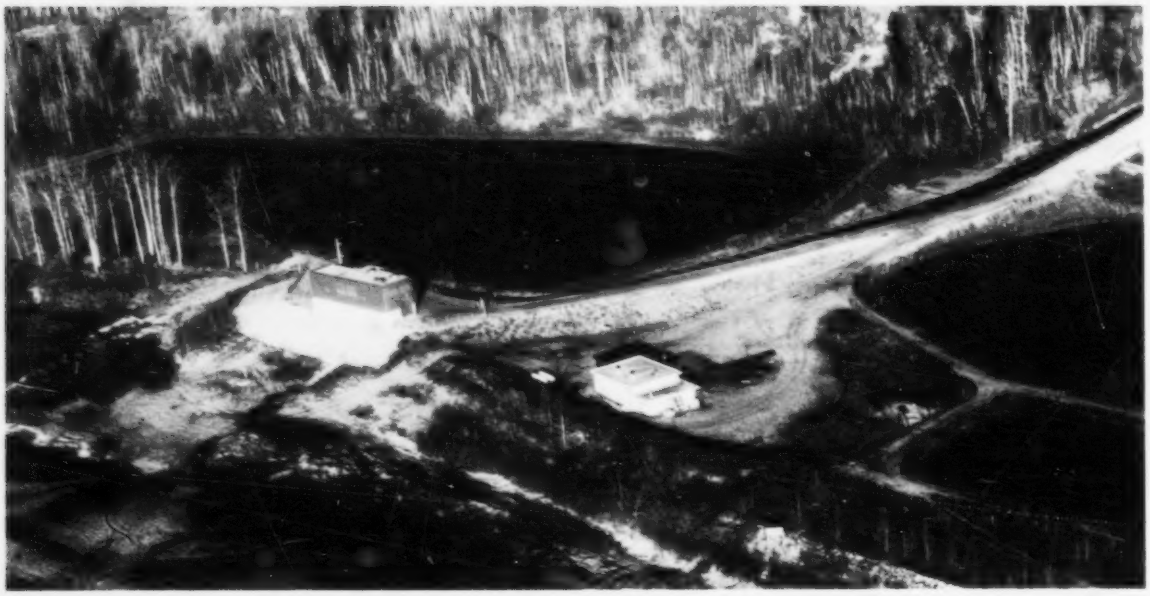
Seismic exploration is used to identify and map oil and gas deposits before drilling. It is based on analyzing how sound waves are reflected from subsurface structures. In Alberta, conventional seismic lines are cleared with a bulldozer, to widths of 6 to 8 m. Then, a series of holes are drilled along the lines, and dynamite is used to create sound waves. These waves are recorded at the surface and allow operators to determine locations of oil and gas fields. The lines tend to be spaced about 400 m apart. From 1979 to 1995, an average of 57,750 km of seismic lines was approved per year in the green zone of Alberta. As of 1995, the total length of seismic lines in the green zone was 1.4 million kilometres. The amount of forest clearing for seismic lines is about the same as that from forestry. The ecological impact of seismic lines is considerable, and includes:

- Progressive loss of forest habitat and extensive fragmentation of forest stands;
- Increased access by off-road vehicles, which impact soil and vegetation and increase poaching;
- Destruction of aquatic habitat through increased stream sedimentation, barriers to fish passage and alteration of drainage patterns.

Since late 1996, much of the exploration for gas and oil in the green zone of Alberta has used low-impact seismic lines, which narrows the line of sight to 200 m. The line width ranges from 1 to 4.5 m, avoids larger standing trees and meanders. It leaves the soil and ground cover undisturbed. In sensitive areas, minimal impact lines must be used. No trees and few shrubs can be cut. Generally, these sites are accessed by helicopter. All seismic lines must be reclaimed.

Since January 2002, all seismic line applications on public lands require the submission of a *Geophysical Field Report*. Applicants must provide site-specific details on how environmental issues will be addressed during the line layout, clearing, operating and reclamation phases of a geophysical program. The applicant must outline how the activity will be conducted to meet environmental standards, rather than having these details addressed by approval conditions. Specific activities are prescribed to protect streams, including crossings and buffers.

Increasingly, forestry and industrial operations work together to reduce environmental impacts. These include using corridors for forestry operations, pipelines, well site access roads and seismic activity. *Integrated Resource Management Plans* will serve as a basis for this cooperation.



Grande Prairie's Old Water Treatment Plant and New Raw Water Pumphouse on Wapiti River (AENV)

Municipalities

Canada and Alberta signed the *Infrastructure Canada-Alberta Partnership Agreement* in October 2000. Under this agreement, up to $513 million is directed to rural and urban municipalities across Alberta, and is cost shared by the federal, provincial, and municipal governments. The program's first priority is "green" municipal infrastructure projects – those related to environmental protection. These include projects related to water and wastewater systems, water management, solid waste management and recycling.

Sewage is a concern because it may contain various quantities of nutrients, organic matter, pathogens and ammonia, which is toxic to fish. All municipalities in Alberta are required to treat their sewage. Levels of treatment range from lagoons in smaller centres to advanced treatment in a few larger cities. Alberta Environment renewed the approval for the City of Grande Prairie Wastewater Treatment Plant for the period 1999 to 2009. The approval required the City to install biological nutrient removal technology (tertiary treatment), and in 2000, changes to the system were begun. Since 2000, ammonia-nitrogen concentrations have dropped by 60% and phosphorus concentrations by 92%. Work is continuing to optimize the system to minimize nutrients and BOD in the treated effluent discharge.

The Town of Jasper upgraded its wastewater treatment facility to tertiary levels in 2002. It includes biological nutrient removal and disinfection before release to the Athabasca River. Approval limits include those for phosphorus, ammonia nitrogen, biochemical oxygen demand, and coliform bacteria. They are required to monitor most of these daily.

Most municipalities in Alberta provide treated drinking water to their citizens. Health Canada, Alberta Environment, and Alberta Health and Wellness all have jurisdictional responsibilities for drinking water quality in Alberta. Alberta Environment approves provincial municipal waterworks systems and promotes formal operator certification programs. Health Canada monitors water systems for First Nations, while the Department of Indian Affairs and Northern Development coordinates training and education of operators. Alberta Health and Wellness regulates drinking water quality in private systems – these are systems not requiring Alberta Environment approval, such as institutions, resorts and rural developments.

The Department of Indian Affairs and Northern Development has funded new drinking water and wastewater treatment facilities at Chipewyan Prairie, Sucker Creek and Garden River. Existing facilities at Fox Lake are being expanded and upgraded to meet present standards. Other facilities are currently being planned for construction or improvements, such as those in the community of Fort McKay. The Mikesew Cree at Allison Bay on Lake Athabasca are cost-sharing the installation of drinking water and sewage systems with the Department of Indian Affairs and Northern Development (DIAND), and will operate and maintain the new systems.

Other initiatives to ensure safe drinking water in Alberta include an *Environmental Health Field Manual* for owners and operators of private systems and a reference manual on toxicity from blue-green algal blooms.

In March 2001, the First Nations (Alberta) Technical Services Advisory Group, Health Canada, and DIAND hosted a workshop for persons involved with the provision of drinking water in Alberta First Nations communities. The purpose of the workshop was to foster awareness of water quality issues and the importance of providing safe drinking water. After the workshop, a Water Quality Steering Committee was established to develop a safe water quality management strategy that is practical and acceptable to all parties involved.

The committee was led by the First Nations Technical Services Advisory Group and consisted of representatives from all areas involved in the provision of safe drinking water. The group reviewed the workshop findings, existing information and the follow-up to the recent water borne disease outbreak in Walkerton, Ontario. As a result, the group decided to develop a water quality management strategy for all First Nations in Alberta based on the Australian Framework for Management of Drinking Water Quality. The framework is a preventive strategy from source to consumer (multi-barrier approach). It integrates risk management principles, provides a comprehensive and flexible means of maintaining the quality of drinking water and is a co-ordinated and proactive approach to protect public health.

Agriculture

Another source of potential pollutants in the northern river basins is agriculture. Crop and livestock production can both affect water quality. Crop growers are increasing their focus on ways to protect water quality by using such practices as reduced tillage, maintaining buffer strips along water bodies, applying nutrients to meet crop nutrient needs, and proper use of pesticides.

Livestock producers are protecting water quality through such practices as manure management, sustainable grazing practices, management of land along water bodies, and proper siting of livestock operations.

Livestock near a Lakeshore (AENV)

The Government of Canada and the provincial and territorial governments are working with the agriculture and agri-food industry and interested Canadians to develop a framework for agricultural policy for the 21st century. Called the *Agricultural Policy Framework*, the objective is for Canada to be the world leader in food safety, innovation and environmentally responsible production. The Framework is made up of the following elements: food safety and quality, environment, science and innovation, renewal and business risk assessment.

Increasingly, farmers and producers are applying many good environmental practices, which increase their profitability and benefit the environment. At the same time, it is clear that more must be done to conserve the environment – consumers increasingly base buying decisions on their desire to support environmental sustainability. Working together under the Agricultural Policy Framework, governments and industry are looking to accelerate efforts to reduce agricultural risks and provide benefits to Canada's water resources, soil, air and bio-diversity.

Alberta's livestock industry entered into a new era on January 1, 2002. The *Agricultural Operation Practices Act* lays a foundation for long-term environmental, social and economic sustainability for the province's livestock sector. The Act includes standards for siting new and expanding confined feeding operations (CFOs) and province-wide environmental standards for all livestock production. It also clearly outlines the specific environmental responsibilities of producers. Under the Act, the *Natural Resources Conservation Board* (NRCB) is responsible for granting permits to new or expanding CFOs. It is also responsible for monitoring and enforcing compliance with province-wide environmental standards and permit conditions in NRCB approvals. The NRCB is an independent, quasi-judicial body reporting to the Minister of Sustainable Resource Development.

> *"The 2002* Agricultural Operation Practices Act *lays a foundation for long-term environmental, social and economic sustainability for the province's livestock sector."*

The *Pesticide (Ministerial) Regulation* and the *Pesticide Sales, Handling, Use and Application Regulation* under the Alberta *Environmental Protection and Enhancement Act* deals with certification of pesticide applicators and dispensers and businesses offering pesticide application and distribution services. Handling, storage and disposal of pesticides is also covered by this regulation. Pesticide applicators, services and vendors are further regulated by the *Environmental Code of Practice for Pesticides*. This Code of Practice is designed to be updated and revised as required and sets out the standards regarding training, supervision, insurance, mixing and loading sites, sales of pesticides to acreage owners and hobby greenhouse owners, etc.

Operation Clean Farm is a three-year stewardship program started in 2002 by CropLife Canada, an industry group made up of manufacturers of crop protection products in Canada, in collaboration with governments across Canada and the agricultural community. It allows farmers to bring old or unused pesticides to a designated location for disposal at no cost to them.

Forestry

Forest ecosystems, which are the predominant land cover in the northern river basins, are both diverse and complex. Both Alberta and the Northwest Territories are committed to managing forest resources in a sustainable and ecologically sound manner. For Alberta, a *Forest Management Agreement* (FMA) is an area-based agreement between the government and a forest company. It gives the company the right to establish, grow, harvest and remove timber from a particular area of land. FMAs require a company to be involved in all aspects of forest management, including long term planning and public consultation. FMAs are renewed every 20 years based on environmental performance and compliance. With long-term tenures, companies share the responsibility for protecting other forest values, such as watersheds and wildlife. As well, companies are required to use long time-lines in their planning. This means that they must account for how the resource will be managed over its life span, which is about 100 years.

The *Alberta Forest Legacy* sets out a management approach for forestry on public lands that goes beyond land management practices designed for single uses, such as timber or oil. It points toward sustainability, not only to maintain the forest economy over the long term, but also to recognize non-market values such as traditional use, fish and wildlife habitat, forest soils and clean air and water. The Alberta Forest Legacy recognizes the importance of learning from the inherent disturbances that have sustained and shaped forests in their evolution, as well as from our own present-day activities. The Legacy calls for activities in the forest to be managed in such a way as to allow the forest landscape to evolve under disturbances similar to those that shaped them in the past.

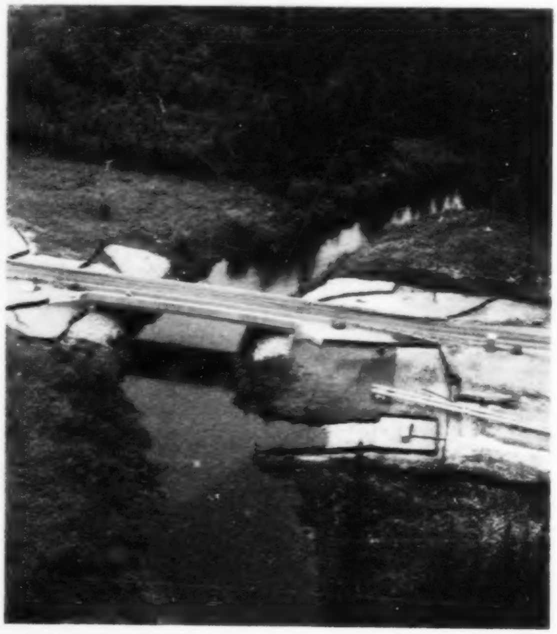
Other Pollution Sources

The Alberta government has released an action plan to reduce greenhouse gases called *Albertans and Climate Change: Taking Action*. It focuses on improving energy efficiency and new technology to control industrial emissions. These will be backed up with regulatory tools and financial consequences for non-participation. It also promotes "green" sources of electricity, such as wind and solar, and removes regulatory barriers for these technologies.

Many other human activities can produce pollutants. These include road building activities and runoff from landfills and coalmines. Most of these activities are controlled by legislation or policies in Alberta.

A large number of road building and heavy construction activities may introduce toxic substances into the environment. In March 2002, Environment Canada and Alberta Environment released the *Pollution Prevention Manual for the Alberta Roadbuilders and Heavy Construction Association*. The document presents environmental issues that are specific to each industry sector. It discusses best environmental management practices for the sector and best practices that are common to all sectors. The manual is intended to get contractors thinking of innovative and proactive ways to prevent the release of toxic substances to the environment and reduce their overall environmental impact. These measures will reduce the consumption of fuels, oils, and lubricants and waste disposal costs. As well, they should give contractors a competitive advantage, because they will avoid costly and time consuming measures to repair environmental damage. Key opportunities to prevent and reduce pollution include:

- Reduce air emissions;
- Reduce fuel and oil consumption;
- Use alternative fuels and products;
- Reduce the occurrence of spills and leaks;
- Improve stormwater management;
- Recycle, reduce and reuse materials.



Muskeg River at Albian Bridge (AENV)

In September 1996, the regulation of all waste management facilities in Alberta was transferred from Alberta Health to Alberta Environment. Municipal waste management facilities fall under the *Code of Practice for Landfills* under the *Environmental Protection and Enhancement Act*. The Code outlines minimum requirements for the construction, operation, and reclamation of landfills to promote environmentally sound management practices. Included in the Code are specifications for landfill liners and leachate collection systems, proper run-off control systems, and ongoing monitoring to ensure containment of the wastes. In addition, the shift towards the development of regional landfills has reduced the number of small landfills operating without the safeguards required of the larger facilities.

Coal mines can be a source of contaminants to surface waters. Selenium is a contaminant of concern in the western part of the study area. Monitoring data have shown elevated concentrations of selenium in surface waters at sites downstream of some foothills coal mining activities in west-central Alberta. Selenium is a naturally occurring trace element that is an essential nutrient for humans and other organisms. But it can be toxic to biota, including fish, at concentrations slightly higher than nutritional requirements. Toxic effects in fish and aquatic wildlife can include deformities, mortality and reproductive failure.

As a result of these findings, a *Selenium Working Group* was formed in late 1999, which includes representatives from the coal industry, Alberta Environment, Alberta Sustainable Resource Development, the Energy and Utilities Board, and the federal Department of Fisheries and Oceans. The overall goal of the working group is to produce a framework and approach for the evaluation and management of selenium at mountain-foothills mines. The group is also a forum for sharing information, and for developing monitoring and research studies. Various selenium studies that are proposed or ongoing include:

- Identification of geological sources;
- Concentrations in water, sediment, aquatic plants and animals, and wildlife;

- Effects on fish reproduction;
- Patterns in streams over time;
- Evaluation of potential treatment options for selenium in water.

Eventually, mechanisms for the control and management of selenium will be developed.

Cardinal River Coals Mining Disturbance (AENV)

The Northwest Territories

In the Northwest Territories (NWT), municipal, territorial and federal governments and co-management boards established under land claims and federal law share the responsibility for environmental and natural resource management. The Department of Indian Affairs and Northern Development (DIAND) is responsible for land and water legislation in the NWT. Examples of this legislation are the *NWT Waters Act* and the *Mackenzie Valley Resource Management Act*. The Government of the Northwest Territories is responsible for legislation such as the *NWT Forest Management Act*, the *NWT Wildlife Act* and the *NWT Environmental Protection Act*.

Releases to surface water and the disposal of waste from industries and municipalities in the Northwest Territories require site-specific approvals or permits. These permits address the conservation and protection of water resources as an underlying principle. Approvals regulate the amount of substances that can be legally released into the environment. In the Inuvialuit Settlement Region, DIAND issues land use permits and the Northwest Territories Water Board issues water licences. Aboriginal land claim legislation can exert significant authority over land and water use. The Gwich'in Land and Water Board, the Sahtu Land and Water Board or the Mackenzie Valley Land and Water Board issues land use permits and water licences. As other land claims are settled, new boards will be established.

The Government of the NWT (Department of Resources, Wildlife and Economic Development) regulates specific resource development activities, such as tourism and forest management. The Canada Department of Fisheries and Oceans regulates fishing.

Cooperative strategies are used to address pollution from other sources within the Northwest Territories. Advice about environmental protection, wildlife management, mining, oil and gas, forest management, municipal and other development is given to permitting agencies by expertise housed within government and various boards and agencies.

Aboriginal groups, the public, non-government organizations, government and its agencies have the opportunity to provide input to permitting processes. If there is a significant public concern or environmental risk (including the social environment), an environmental assessment is undertaken. The *Mackenzie Valley Environmental Impact Review Board* and the *Environmental Impact Review Board (Inuvialuit Settlement Region)* are responsible for conducting environmental assessments of developments referred to them. The Review Boards will recommend to the appropriate ministers whether or not a project should go ahead. If the project goes ahead, the Review Boards will recommend ways to protect the environment from impacts.

The *NWT Environmental Protection Act* prohibits the discharge of contaminants into the environment except when authorized by certain permits or agreements. Although pesticide use in the Northwest Territories is limited, its application is regulated under the *NWT Pesticide Act*. The Northwest Territories Department of Resources, Wildlife and Economic Development is responsible for this Act.

The Government of the Northwest Territories has developed *Managing Drinking Water Quality in the NWT - A Preventative Framework and Strategy* through its Departments of Public Works and Services, Health and Social Services, Municipal and Community Affairs and Resources, Wildlife and Economic Development. This framework recognizes the need for many to work together to maintain good drinking water quality in the NWT. Actions are outlined in three focus areas:

- Keeping NWT Water Clean;
- Making Drinking Water Safe, and
- Proving Drinking Water is Safe.

This framework is based on a nationally and internationally accepted multi-barrier approach to drinking water quality issues that is known as "Source to Tap". It implies that the entire drinking water system is to be managed as a whole, so that the source is protected and water is properly treated and distributed. Public Works and Services is undertaking reviews of all community water supply systems, updating facilities and initiative improvements. As well, drinking water treatment operators in northern communities are taking part in training and certification through he Department of Municipal and Community Affairs with the assistance of other departments. Public information on drinking water quality is available through an Internet site.

Slave River below Fort Smith (Wayne Starling, INAC)

Monitoring

Monitoring activities are ongoing in the northern river basins. Monitoring, including routine sampling programs, provides information on the state of the environment over a specific time period. The environment varies naturally over the seasons, from place to place and over years. Therefore many samples may be needed to determine effects from human activities. A series of samples can establish trends over time.

Monitoring requires reliable and accurate data. Most scientific studies take specific measures to assure the quality of data being collected. If this is not done, wrong conclusions may be drawn. Environmental data help us to:

- Define problems and issues
- Set goals and guidelines for environmental protection
- Know how we are performing, and
- Design management measures to protect the environment.

Monitoring Networks

Water is usually monitored at fixed stations. This helps to standardize the data so they can be compared from day to day and year to year. Many monitoring stations have been in place for decades, which provides a long-term view of flow or water quality.

Hydrometric Gauge at Jackpine Creek (AENV)

Water Quantity

Water in lakes, rivers and streams can only be managed if we know its quantity. Flow volume in rivers is an essential part of any monitoring or research study. Flows are measured as the amount of water passing the station in a given time, usually as cubic metres per second. Through the Water Survey of Canada, a hydrometric station network is cost-shared and jointly operated by Environment Canada and Alberta Environment. The purpose of the network is to provide data for:

- Water apportionment agreements between jurisdictions;
- Operating major structures such as dams, irrigation projects and canals;
- Flood and water supply forecasting;
- Understanding the resource in terms of quantity, location, seasonality, variability, regional patterns, peaks, frequencies and trends;
- Supporting other data requirements such as water quality monitoring; and
- Project-specific monitoring requirements.

In Alberta, there are about 70 hydrometric stations operating in the Peace/Slave River basin and 80 stations in the Athabasca River basin. The majority of these provide streamflow data, although some lake levels are also monitored.

Alberta maintains a separate lake network throughout the province in which lake levels are monitored seasonally. There are about 17 lakes in the Peace basin and 40 lakes in the Athabasca basin under this program.

In the Northwest Territories, there are federal hydrometric stations on a number of rivers, including tributaries to Great Slave Lake. Water levels on Great Slave Lake are monitored at Yellowknife Bay and Hay River.

Surface Water Quality

Stations are also present throughout the northern basins to monitor water quality. Environment Canada monitors water quality at sites in the national parks and at boundaries between provinces and territories. In the northern basins, there are federal sites in Jasper and Wood Buffalo National Parks and on the Peace, Slave and Hay rivers.

Provincial water quality monitoring in northern Alberta began as early as the 1950s. Since then, Alberta Environment has set up a network of monitoring sites and conducted shorter-term surveys at various locations. It uses ongoing river monitoring data to assess the effectiveness of its regulatory processes in protecting the rivers from toxic substances, nutrients, metals and other contaminants. The *Long-Term River Network* is based on monthly samples collected at eight critical sites along the Peace, Athabasca, Wapiti and Smoky rivers. A secondary network was set up in the late 1980s to collect information on specific issues, such as the impact of expanding industrial activity.

Monitoring is also used to address specific short-term needs on selected water bodies, and for seasonal issues and concerns. An example of the latter is the real-time winter monitoring of dissolved oxygen (DO) on the Athabasca River system. This has been in place since 1989.

Water Quality Sampling on the Athabasca River (AENV)

Stations are also present on lakes. The focus of the Long-Term Lake Network, which began in 1980, is to monitor levels of nutrients and algae to make sure recreational water quality remains good. Northern lakes in this network are Baptiste Lake near Athabasca and Nakamun Lake northwest of Morinville. Samples are collected monthly during the open-water period, and once in winter.

In partnership with the *Regional Aquatic Monitoring Program* (RAMP) (*see more information on p. 46*), Alberta Environment samples an additional set of 50 lakes to determine changes from acid deposition. The lakes, which are a part of hundreds that were sampled in the mid-1980s, are located in the northeastern part of Alberta, including a part of the NREI study area. A majority of lakes in the region are not sensitive to acid deposition because they have high alkalinities (acid-neutralizing capacities) and receive runoff from mineral soils. However, some of the lakes are considered sensitive because they have low alkalinities as a result of their inflows originating from shallow, acidic, organic soils.

Monitoring stations were also set up on five selected streams in the northern basins to assess trends in stream water quality in relation to trends in agriculture. This monitoring network is a part of the *Alberta Environmentally Sustainable Agriculture* (AESA) program.

In the Northwest Territories, DIAND operates a number of water quality monitoring programs. One of these is an instrument installed at the Fort Smith water intake, which continuously monitors temperature, dissolved oxygen, turbidity and other characteristics. Samples are also collected periodically at this site and analyzed for metals, nutrients and bacteria. Monthly samples are collected from the Slave River at Fort Smith and other local rivers. Long-term water quality sample sites with a monthly sampling frequency are maintained on a number of rivers.

The *Slave River Environmental Quality Monitoring Program* is considered to be the most comprehensive water quality study ever completed in the Northwest Territories. DIAND and the Government of the Northwest Territories conducted the study. The purpose of the monitoring program was to assess the current status of the Slave River to discover any hazards to human health or the aquatic environment, and to establish a solid baseline to see if conditions change in the future. Over the course of the program, water, sediment and fish samples were tested for about 240 different chemicals, particularly those associated with pulp and paper mills, agricultural development, and oil and gas development. An additional sampling program was completed in 2003, five years after the first sampling. Fish tissue data from the Slave River Environmental Quality Monitoring Program have been submitted to the Government of the Northwest Territories Health department and Health Canada for an assessment of human health implications. A report on monitoring results is being prepared.

Air Quality

Air quality in northern Alberta is a growing concern. The largest air-monitoring network is located in northeastern Alberta and is operated by the *Wood Buffalo Environmental Association* (WBEA). WBEA is a dynamic collaboration of Aboriginal communities, environmental groups, industry and government in the Regional Municipality of Wood Buffalo (Fort McMurray and the oil sands area).

WBEA operates thirteen state-of-the-art continuous monitoring stations. Its focus is on air quality and air-related environmental impacts. People can use the information generated to make informed decisions that relate to their health, safety, quality of life and traditional land use. Some of the topics being addressed include:

- Human health,
- Odours, smoke and dust,
- Soil and water acidification,
- Ground-level ozone,
- Heavy metals deposition and accumulation,
- Greenhouse gases.

The *Terrestrial Environmental Effects Monitoring Program* under WBEA operates a long-term program to characterize and quantify the extent to which air emissions are affecting terrestrial and aquatic ecosystems. A report on heavy metals in fish, vegetation and mammals is nearing completion.

The Peace Airshed Zone Association samples air quality at 48 passive monitoring sites in the Grande Prairie and Peace River areas of northwestern Alberta. Alberta Environment also monitors air quality in northwestern Alberta near Beaverlodge. The main focus of the Beaverlodge station is to check transboundary transport of air pollutants between British Columbia and Alberta. Air quality and acidic deposition are monitored at the Beaverlodge station. In addition to airshed zone monitoring programs, industries in Alberta are required to monitor air quality downwind of their facilities as part of their environmental Approval. Air quality data from provincial and airshed zone monitoring programs is made available to the public through a central database management system managed by the Clean Air Strategic Alliance.

As in Alberta, citizens of the Northwest Territories are becoming concerned about air quality. Industrial development is increasing, and emissions potentially can impact air quality as well as land and water quality through deposition of a variety of substances. As a result, the Department of Resources, Wildlife and Economic Development of the Government of the Northwest Territories is expanding its monitoring of air quality in northern communities. A monitoring station in Yellowknife has been upgraded and new stations are located in Inuvik, Norman Wells, Ft. Liard and Ft. Simpson. The expanded monitoring network, run jointly with Environment Canada, will provide baseline air quality data for these communities.. This allows agencies to track changes in air quality that may arise from industrial and community emission sources.

Use of Data

Environmental data are used for a variety of purposes. An important use is to compare measurements in water, soil, air or sediment with guideline levels established to protect those environments. Another use for data is to compare water quality upstream and downstream of impact areas on a river or stream, or over time. A further use is to make sure human health is protected.

Environmental Guidelines

An environmental guideline is a numerical concentration or statement recommended to protect a designated use in water, air, soil or sediment. Unlike an approval limit, it has no legal ramifications. When a guideline level is exceeded, however, it can raise a "red flag", and causes can be investigated. Then, the appropriate action can be taken. Alberta and the Northwest Territories may use these guidelines to help set discharge limits for municipal and industrial approvals.

In 1987, the Canadian Council of Ministers of the Environment (CCME) published the *Canadian Water Quality Guidelines*. Since then, environmental concerns have increased, but so has our understanding of the multiple threats to ecosystem health. Canadians have recognized the need to protect parts of the ecosystem in a more complete way. In 1999, the CCME published the *Canadian Environmental Quality Guidelines*. This two-volume document is the world's first integrated document of its kind. It lists guidelines for air, surface water, community water supplies, soil, sediment, and tissue residues (the latter as a tool to assess bio-accumulation trends in wildlife). These guidelines are nationally endorsed, science-based goals for environmental quality. The guidelines assume that if a concentration in the environment is below the stated guideline, there should be little risk to plants and animals or a designated use.

The most protective water quality guidelines are generally those for aquatic life. Alberta has guidelines for the protection of aquatic life for 122 substances and characteristics (*Surface Water Quality Guidelines for Use in Alberta*). These have been compiled from new and previous Alberta guidelines, CCME guidelines and US Environmental Protection Agency criteria. Other categories for water quality guidelines include those for agricultural uses and recreation/aesthetics.

One of the Alberta guidelines is designed to protect fish and their food organisms. Fish need to have a certain amount of dissolved oxygen in the water to live. For dissolved oxygen, an Alberta guideline level of 6.5 mg/L for a seven-day average was set (the chronic guideline), with 5.0 mg/L for an instantaneous minimum (the acute guideline). The guideline assumes that fish and other aquatic life will be protected if dissolved oxygen remains above these levels. As well, the Alberta guideline is increased to 8.3 mg/L from mid-May to the end of June to protect mayfly emergence, and to 9.5 mg/L during fish spawning, egg incubation and hatching periods (*see further information in the Scientific Findings section, p. 92*).

Surface water quality guidelines do not apply to drinking water. The *Guidelines for Canadian Drinking Water Quality*, published in 1996, apply to treated water for drinking. Each spring, additions and changes to the guidelines are listed on the Internet.

Water Quality Index

Another use of data is for the *Alberta River Water Quality Index*. It is based on monthly samples collected year round at long-term monitoring sites on major rivers throughout the province. Its purpose is to maintain or improve the water quality in Alberta's rivers. The Index is calculated from the data for four groups of water quality substances: metals, pesticides, bacteria and nutrients. Figure 8 shows the results of the water quality index for the Peace and Athabasca rivers. For the period 1996-2002, water quality in these rivers has remained good or excellent. The differences in the index numbers for these years results from climatic variation – when conditions are wet, runoff increases and the rivers become more turbid. This tends to make the value lower. But when conditions are dry, the reverse is true, and the value is higher. Based on these chemical groups, there is no evidence that water quality is deteriorating in either of these rivers.

Protection of Human Health

Major public issues that resulted in the implementation of the NRBS and the NREI concerned human health – was it safe to drink the water and eat fish from northern rivers. Steps have been taken to address these issues over the past few years.

Many Northern traditions revolve around food gathering. Traditional foods are important because of their superior nutritional value and their spiritual and cultural significance. In the late 1980s, scientists found that the air, water, plants, animals and people were being exposed to contaminants that are released into the environment from sources outside of the North. The kinds of contaminants found in the north include persistent organic pollutants, heavy metals and radionuclides. The *Northern Contaminants Program* was created to assess effects of contaminants on the environment and people, and help people make informed decisions about their food use. The program is managed by DIAND, with partners from governments and First Nations.

Alberta Environment and Alberta Health and Wellness, in conjunction with the Provincial Laboratory for Public Health, Regional Health Authorities and Health Canada, have formalized a protocol to deal with bacteriological sample results that exceed drinking water guidelines. This protocol deals with emergency situations when the samples fail any coliform test. The protocol deals only with those water treatment systems approved by Alberta Environment. The protocol involves the owners and operators of systems, who are ultimately responsible for drinking water quality.

Alberta Environment, in collaboration with Alberta Health and Wellness, is reviewing all approved waterworks systems to make sure they can continue to supply safe drinking water well into the future. This initiative, which is funded by *Water For Life*, is looking at all aspects of providing safe drinking water, from the source water to the water coming out of the tap. The project will identify long-term solutions and their costs.

Figure 8. *Alberta River Water Quality Index for 2000-2001. (AENV)*

Alberta Surface Water Quality Index - '01/'02

	Previous years					Reporting year	Comments
	96/97	97/98	98/99	99/00	00/01	01/02	
SMOKY/PEACE RIVERS							
at Watino	84	83	91	90	93	94	Conditions are ranked as excellent at both sites. Index values have improved not meet guidelines. The index value has declined slightly at Ft. Vermilion this period, primarily due to some high spring nutrient concentrations associated with high suspended solids concentrations.
at Ft Vermilion	86	89	94	86	93	88	
ATHABASCA RIVER							
at Athabasca	91	92	90	91	97	99	Conditions are ranked as excellent at both sites. Index values have improved slightly at Athabasca and Old Fort, perhaps reflecting a general decrease in runoff and lower suspended solids concentrations, associated with drier conditions.
at Old Fort	90	90	95	91	94	97	

Water Quality Category Descriptions for the Alberta Surface Water Quality Index

96 - 100	Guidelines almost always met: "Best" Quality **(Excellent)**
81 - 95	Guidelines occasionally exceeded, but usually by small amounts; threat to quality is minimal **(Good)**
66 - 80	Guidelines sometimes exceeded by moderate amounts; quality occasionally departs from desirable levels **(Fair)**
46 - 65	Guidelines often exceeded, sometimes by large amounts; quality is threatened, often departing from desirable levels **(Marginal)**
0 - 45	Guidelines almost always exceeded by large amounts; quality is significantly impaired and is well below desirable levels; "Worst" Quality **(Poor)**

A new way to provide information to the public on drinking water quality is an Internet reporting program. Each municipality will be required to submit data on treatment plant performance electronically. Interested people can compare data from each plant with established guidelines.

In May of 2003, the federal government announced a new initiative to deal with the safety of drinking water in First Nations communities and released the "*Water: Source of Life*" information kit. This work by Health Canada and Indian and Northern Affairs Canada has culminated in the development of a *First Nations Water Management Strategy* to be implemented over 5 years.

Fish consumption advisories have been set up to protect people from harmful effects of mercury and other contaminants in fish they eat. The *Public Health Management Committee*, which is composed of people from Alberta Health and Wellness, Alberta Environment, Alberta Sustainable Resource Development and local regional health authorities, reviews fish assessments and recommends whether or not an advisory should be changed.

In 2002, a scientific review and testing of mountain whitefish, burbot and bull trout muscle in the Athabasca River basin found that levels of dioxins and furans were within Health Canada guidelines. As a result, the advisory for dioxins and furans was removed. But the advisory for burbot liver continues, because of concerns with levels of these chemicals in this organ.

The advisory for dioxins and furans on the Smoky/Wapiti river system was revised in 2000 to allow for the consumption of four servings of Mountain Whitefish per week. As an added precaution, pregnant women and young children are advised to avoid consumption of Mountain Whitefish from this river system. People should not eat burbot liver, as there were continuing concerns about levels of dioxins and furans in these tissues.

Mercury can be passed through the food chain and become concentrated in fish-eating species such as Northern Pike and Walleye. Where mercury is present, the larger fish generally have higher concentrations in the liver, kidney and muscle. Health Canada has set fish consumption guidelines based on the concentration of mercury in fish tissue, and on the human body's ability to eliminate mercury at a slow rate. In Alberta, most of the mercury in fish appears to come from natural sources in soils and sediments.

There is a mercury advisory for Walleye in the Athabasca River, and for several species in a few lakes. In general, women of childbearing age and children under the age of 15 should not eat these fish. Details may be found in the *Alberta Guide to Sportfishing Regulations*. You should check the most up-to-date advisories, because they are reviewed regularly and may change from year to year.

In the early 1990s, levels of toxaphene in the livers of burbot caught in the Slave River at Fort Smith were sufficiently high that the consumption of this organ could pose a health hazard to the consumer. Therefore, it is suggested that the liver of burbot from the Fort Smith area of the Slave River not be consumed. This advisory is still in effect since there has not been any new data made available for health risk assessment. The Government of the North West Territories Department of Health and Social Services recommends that burbot be resampled to see if this advisory is still warranted.

Data Quality

Sampling procedures and laboratory analyses must be conducted with scrupulous attention to standard methods. Laboratories used for analyzing samples must be accredited. Environment Canada has a policy that requires accreditation, and the *Canadian Environmental Protection Act* has a section that allows Environment Canada to specify the use of accredited facilities. In the United States, almost every state requires that accredited facilities be used for environmental analyses. Alberta Environment has recognized that data must be credible to both the public and the regulated industries to be effective. The *Laboratory Data Quality Assurance Policy* ensures that data used for compliance assessment, environmental assessments and performance measures are of the best quality possible. Consistent application of this policy will set uniform, clear and objective standards for all environmental data submitted to Alberta Environment by municipalities, industry, analytical laboratories and research establishments.

Industrial Impacts

In both Alberta and the Northwest Territories industrial effluents and receiving waters are monitored according to terms specified in operating approvals. The data from effluent samples must meet specific release limits. For example, a pulp mill is allowed to discharge only a certain amount of BOD per day. Industries may also be required to monitor chemical and physical characteristics in the receiving water, and where necessary, conduct invertebrate and fish surveys for the purpose of environmental effects monitoring. All monitoring information collected in accordance with approval conditions is submitted to regulatory agencies, and is available to the public.

Pulp Mills

The pulp and paper industry is required to conduct *Environmental Effects Monitoring* (EEM) under the *Pulp and Paper Effluent Regulations* of the *Fisheries Act*.

Information from EEM is used to evaluate the effects of industrial effluent on aquatic environments, and to assess the adequacy of regulations to protect aquatic resources. EEM is not just an end-of-pipe measurement of the concentrations of various contaminants in effluent. Fish and benthic invertebrates are also monitored in the receiving water to determine if the effluent is having any effects. The five elements of the EEM program are: 1) an adult fish survey, 2) a benthic invertebrate community survey, 3) measurement of effects on the use of fisheries resources (some mills may be required to analyse chlorinated dioxin and furan levels in fish tissue, and conduct a fish tainting study), 4) effluent toxicity tests and 5) chemical tracers in fish. The goal of the monitoring is to answer four questions:

- Is there an effect?
- Is the effect caused by mill effluent?
- What is the magnitude and extent of the effect?
- What is the cause of the effect?

An effect is defined as a statistically significant difference between measurements from reference areas (no mill effluent) and exposure areas (receiving mill effluent inputs).

EEM is structured in three to four-year sequences of monitoring, interpretation, and reporting known as "cycles." Cycle 1 (1992 to 1996) and Cycle 2 (1996 to 2000) have been completed, and Cycle 3 will be completed in 2004. At the beginning of a cycle, each mill develops a study design that is submitted to Environment Canada and reviewed by a Technical Advisory Panel consisting of federal and provincial members. The purpose of the Panel is to make sure that EEM requirements are met and that the studies are scientifically sound. After the study design is accepted, the mill conducts the field study. At the end of each cycle, the mill submits an Interpretive Report to the Technical Advisory Panel. The report summarizes the monitoring program and interprets the results. The mill uses the study findings to design the field study for the next cycle.

Pulp Mill Effluent to Athabasca River, 1991 (AENV)

Environmental Effects Monitoring

Environmental Effects Monitoring (EEM) is a scientific tool that assesses the effects of pulp mill effluent on fish, fish habitat and the human use of fisheries resources. The following focuses on Cycle 2 results, the most recently completed cycle (1996-2000). For Cycle 2, the five mills on the Athabasca River worked together to produce a joint report on their findings. One mill on the Peace River and one mill on the Wapiti River also conducted EEM.

Six Cycle 2 adult fish surveys were conducted during September and October 1998. All fish survey designs included a reference area upstream of the effluent discharge and an exposure area immediately downstream of the effluent discharge. Most mills conducting the fish survey used longnose sucker and a small-bodied species as monitoring species; one mill was not able to catch sufficient numbers of a small-bodied fish.

Generally, the two mills located furthest upstream on the Athabasca River reported that fish in the exposure area were bigger for their age and had increased body condition compared to those in the reference area. As well, longnose suckers and spoonhead sculpin in the exposure area of the mill located furthest upstream in the Athabasca River had heavier livers and larger gonads. In contrast, mills located further downstream on the Athabasca River reported decreases in body condition and/or lighter livers and smaller gonads for at least one species in the exposure areas. Effects found in fish in the exposure area on the Wapiti River were similar to those found in the upper Athabasca River, including increases in size and body condition for both longnose sucker and longnose dace.

During the fish surveys, the external condition of fish was observed to note any abnormalities, lesions, tumours and/or parasites. The most common external conditions were fin erosion, gill discoloration, and the presence of parasites. Several studies included internal examinations as well, noting liver fat storage and enlarged spleens. Although abnormalities were noted in the reference areas at all mills, some were seen more frequently in the exposure areas.

Conclusions about mill-related effects on fish are limited because study designs were often different between Cycles 1 and 2. As well, other factors – for example, sewage effluent in the area – made it difficult to isolate possible mill effects. Study designs in future cycles will remove such "confounding factors".

Six of the seven mills conducted the Cycle 2 invertebrate community surveys in conjunction with the fish surveys. The remaining mill conducted their survey during the fall of 1999. Study designs included at least one reference area upstream of effluent discharge, and exposure areas immediately below the pulp mill effluent discharge, as well as further downstream where effluent levels were lower. In general, the monitoring programs found that the abundance and types of invertebrates were higher in exposure areas. However, as with the fish surveys, conclusions regarding mill related effects are limited.

For each cycle, the pulp mills are required to test for toxicity once in summer and once in winter. Three species of aquatic organisms are used – a minnow, an invertebrate and an alga. In Cycle 2, there was only one report of reduced minnow growth. Results from the invertebrate tests were variable, and all mills reported at least three tests that indicated inhibited reproduction. Similarly, results on the growth of the algae were variable, although inhibited algal growth was reported for at least two tests at all mills. However, effluent toxicity was generally reduced since Cycle 1.

Studies during Cycle 2 benefited from the experience of Cycle 1: study designs improved, leading to greater sample sizes and fewer problems in sorting out effects. Cycle 3 promises to contribute substantial findings, and should confirm the effects (or lack of effects) found during Cycle 2. It may also provide information on the magnitude and extent of confirmed effects. Subsequent cycles should further clarify the causes and longer-term patterns of mill related effects.

Summary of Cycle 2 Environmental Effects Monitoring Results from Pulp and Paper Mills in the Northern River Basins.
J. Ferone and S. Blenkinsopp.

Oil Sands

The oil sands industry can have a major impact on the land and water. In 1997, the industry established the *Regional Aquatics Monitoring Program* (RAMP) to carry out aquatic surveys and monitoring in the Athabasca oil sands area. RAMP is a multi-stakeholder initiative with representation from industry, aboriginal groups, and federal, provincial and municipal governments. The mandate of RAMP is to determine, evaluate and communicate the state of the aquatic environment in the area. RAMP is designed as a long-term monitoring program with sampling frequencies ranging from continuous or seasonal to once every few years. The sampling program includes surveys of water quality, sediment quality, benthic invertebrates, fish, wetlands, vegetation, climate and hydrology. The data collected through the program will be used to detect cumulative effects and regional trends.

As well, baseline conditions will be established and predictions in the *Environmental Impact Assessments* can be verified. The study area for RAMP has recently been revised to include the Regional Municipality of Wood Buffalo and the OPTI site (Long Lake area) south of Fort McMurray.

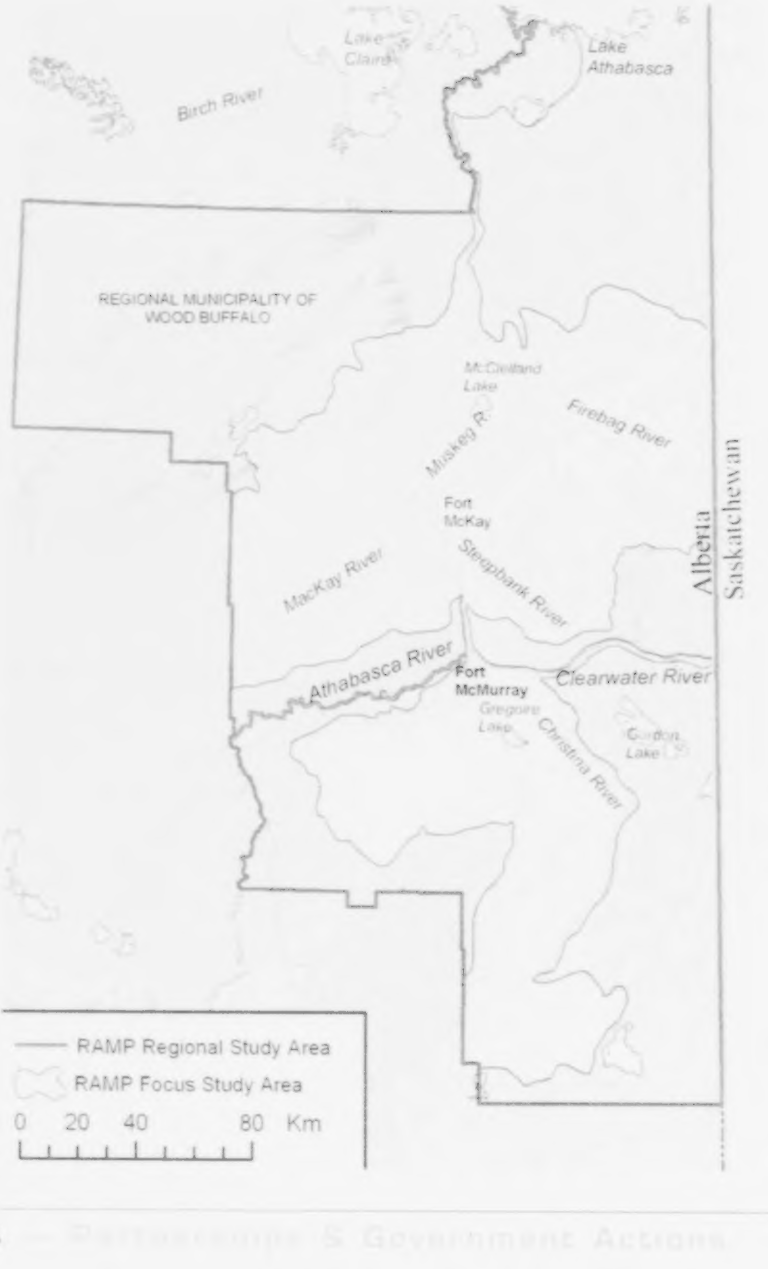

Lake Claire
Lake Athabasca
Birch River
REGIONAL MUNICIPALITY OF WOOD BUFFALO
McClelland Lake
Firebag River
Muskeg R.
Fort McKay
Alberta
Saskatchewan
MacKay River
Steepbank River
Athabasca River
Fort McMurray
Clearwater River
Gregoire Lake
Gordon Lake
Christina River
RAMP Regional Study Area
RAMP Focus Study Area
0
20
40
80
Km

Figure 9. *Study area of the Regional Aquatics Monitoring Program (RAMP), 2004*

(Oil Sands RAMP)

Oil Sands

The oil sands industry can have a major impact on the land and water. In 1997, the industry established the *Regional Aquatics Monitoring Program* (RAMP) to carry out aquatic surveys and monitoring in the Athabasca oil sands area. RAMP is a multi-stakeholder initiative with representation from industry, aboriginal groups, and federal, provincial and municipal governments. The mandate of RAMP is to determine, evaluate and communicate the state of the aquatic environment in the area. RAMP is designed as a long-term monitoring program with sampling frequencies ranging from continuous or seasonal to once every few years. The sampling program includes surveys of water quality, sediment quality, benthic invertebrates, fish, wetlands, vegetation, climate and hydrology. The data collected through the program will be used to detect cumulative effects and regional trends.

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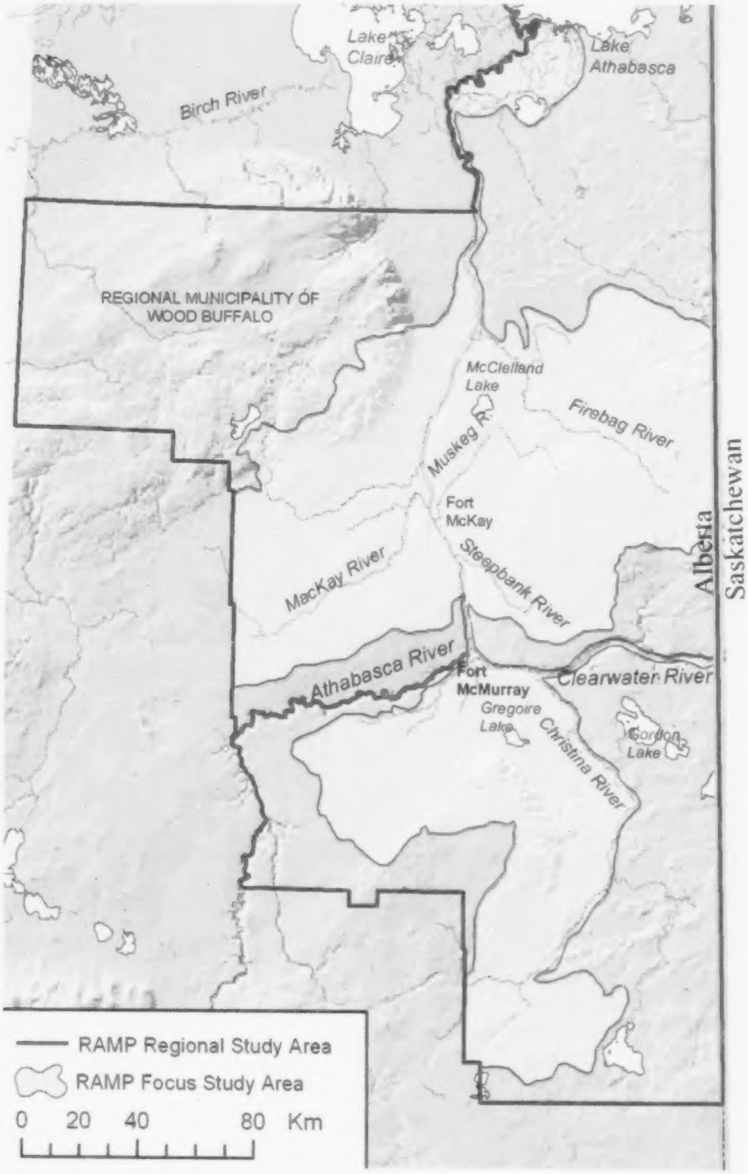

Lake Claire
Lake Athabasca
Birch River
REGIONAL MUNICIPALITY OF WOOD BUFFALO
McClelland Lake
Firebag River
Muskeg R.
Fort McKay
MacKay River
Steepbank River
Alberta
Saskatchewan
Athabasca River
Fort McMurray
Clearwater River
Gregoire Lake
Christina River
Gordon Lake
RAMP Regional Study Area
RAMP Focus Study Area
0 20 40 80 Km

Figure 9. *Study area of the Regional Aquatics Monitoring Program (RAMP), 2004.*

(Oil Sands RAMP)

Research

Research is a scientific protocol to answer a specific question or questions. For example, "What is the effect of pulp mill effluent on fish reproduction?" Sometimes monitoring and research overlap, and quite often data from monitoring programs can be used in research. Research was a major focus for the NREI, so that NRBS recommendations could be addressed.

Environment Canada and other federal jurisdictions are involved in environmental research. Many of the scientists who worked on NRBS and NREI are with the National Water Research Institute. These scientists are leading the way in recognizing new threats to the quality and quantity of freshwater. They are producing the scientific knowledge needed by policy makers and governments to act swiftly to confront these threats.

Climate Change

The *Mackenzie Global Energy and Water Cycle Experiment* (MAGS) is part of an international effort of the *World Climate Research Programme*. The goal of MAGS is to improve our understanding of the water and energy cycle of the Mackenzie River Basin in particular and of cold regions in general. One of its major objectives is to develop coupled models of the atmospheric and hydrological processes of the Mackenzie River Basin. These can be used to evaluate the impact of both human-induced climate change and natural climate variability on Canada's water resources. A major accomplishment of MAGS has been to demonstrate the magnitude of the components of the water cycle at a monthly time scale. The study found strong evidence that deviations or anomalies in climate are greater in winter than in summer. It also found linkages between the amount of precipitation that falls in the basin and climatic events in the Pacific Ocean.

Great Slave Lake

In recent years, industrial development along the Peace and Athabasca rivers has raised concerns that persistent organic pollutants could be transported via the Slave River into Great Slave Lake. Also of concern is the long-range atmospheric transport of pollutants to the region from other industrialized parts of the world. To get a clearer picture of the extent and sources of the problem and its effects on the food chain, researchers from Environment Canada's National Water Research Institute and Fisheries and Oceans Canada began a series of studies under the *Northern Contaminants Program* and the *Northern River Basins Study*.

The scientists collected water, sediment and biological samples from the lake. They found that persistent organic pollutants were present in sediments, particularly from the Western Basin. These chemicals were also present in fish and other aquatic organisms. In 1999, a new study was launched with community partners from Lutsel K'e and Fort Resolution to monitor long-term trends in contaminant concentrations in fish in Great Slave Lake. Researchers believe that contaminant concentrations in Great Slave Lake will decrease as atmospheric sources decline.

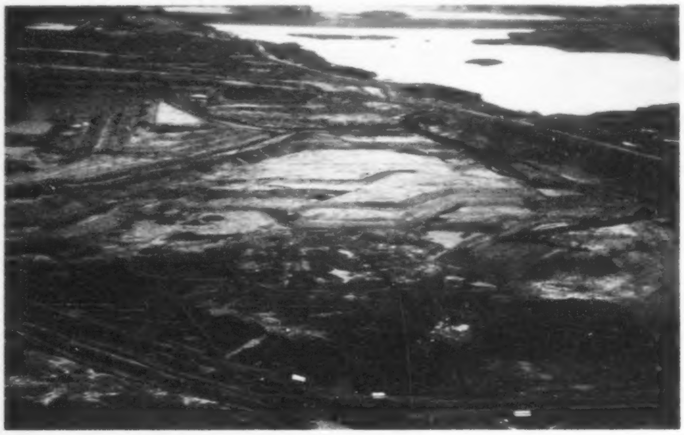
Oil Sands

Environment Canada began a four-year research project in 1998 to define the origins and impacts of oil sands materials in surface waters. The project was funded through Natural Resources Canada's *Panel on Energy Research and Development* (PERD). The research assessed potential impacts of oil (hydrocarbon) extraction activities in the Alberta oil sands area. In particular, the study looked at impacts produced by naturally occurring hydrocarbon deposits and releases. The primary objectives were to:

- Improve our understanding of the nature and extent of natural and industrial hydrocarbon releases to the environment within the oil sands region of northern Alberta.
- Distinguish between effects from natural versus industrial releases of oil sands contaminants to the environment.
- Develop and field validate ecological tests that provide early warning of the impacts of oil sands-related contaminants on biota.
- Integrate the findings into an environmental assessment and monitoring framework for the oil sands industry.

This research is intended to develop environmental models and indicators that will be used by the industry to distinguish between natural and industrial impacts. These indicators can then be used to assess and monitor these impacts and, where necessary, to develop appropriate strategies to restore the natural environment. The study concluded in 2003. Results of the PERD studies are summarized in the Major Scientific Findings chapter in this report.

The *Canadian Oil Sands Network for Research and Development* (CONRAD) is a network of companies, universities and government agencies organized to facilitate collaborative research in science and technology for Alberta oil sands. Although much of the research is related to extraction of oil from the oil sands, its Environmental Research Group is involved in environmental issues. These include, among others, projects on contaminants and the effects of process-affected water on wetlands and fish health.



Oil Sands Mining Operation (Environment Canada)

One focus of the CONRAD Environmental Research Group is reclamation of oil sands lands. Reclamation in the oil sands has been under development for nearly 30 years, with many research and monitoring projects supporting this activity. The land area to be reclaimed is increasing rapidly and some of the areas will be challenging to reclaim. As a result, reclamation has been integrated into long range planning, operations and closure. As well, the costs of reclamation must be assessed as well as the ability of reclamation practices to achieve a sustainable landscape.

The *Oil Sands Environmental Research Network* is a national research network based at the University of Alberta and funded by the oil sands industry. One of the objectives of this network is to foster and facilitate reclamation research programs for oil sands projects. A major goal of this research is to evaluate ecosystem establishment after reclamation, and the long-term sustainability of reclaimed sites. The goals of the Network are:

- To promote, facilitate and integrate environmental research that impacts oil sands reclamation;
- To encourage other Canadian universities and research institutes with expertise in oil sands reclamation issues to enter into arrangements with the University to participate in the activities of the Network.
- To make communication, collaboration and exchange of information on reclamation research easier for Network participants.

Although the oil sands area is currently highly disturbed, establishing self-sustaining plant communities is under way. Eventually, an ecosystem should develop that is similar to that of the surrounding areas, and reclaimed areas should integrate into the natural landscape. The long-term plan for the reclaimed areas is to establish a mosaic of self-sustaining forests, grasslands, wetlands and lakes to protect and maintain water quality, provide habitat for wildlife, create recreational opportunities, and produce commercially useful timber.

Agriculture

The *Alberta Agricultural Research Institute* (AARI) is the primary agency in Alberta for funding, coordinating and promoting strategic agricultural research initiatives and technology transfer in the agriculture and food sector. The Institute was established by the Alberta *Science and Research Authority Act* and funds numerous projects each year that play a significant role in advancing Alberta's position as a global player in the agriculture and food sector. One of the key research areas is environmental sustainability.

The *Alberta Livestock Industry Development Fund* and the *Alberta Crop Industry Development Fund* are two funding consortiums that have linked their approvals process with AARI.

The *Alberta Environmentally Sustainable Agriculture* (AESA) program began in 1997. Its purpose is the continued development and adoption of management practices and technologies that make agriculture more environmentally sustainable. AESA is an ongoing provincial program that relies on the partnership between Alberta Agriculture, Food and Rural Development; Alberta Environment; Alberta Health and Wellness; and the private sector.

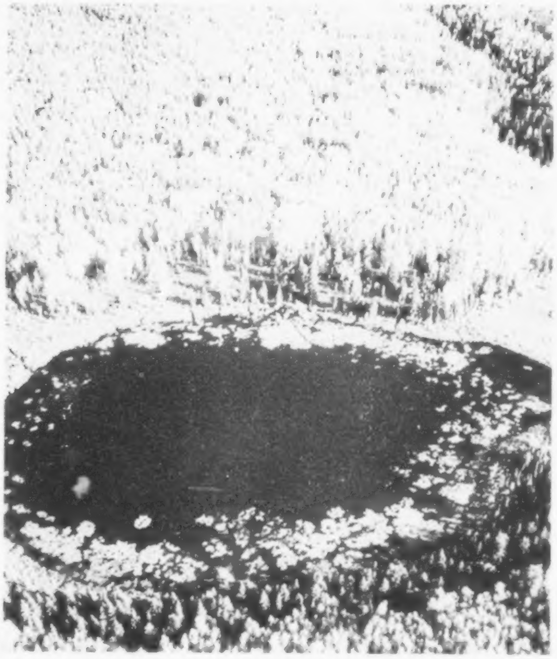
Smoky River upstream of Wapiti River (AENV)

Forestry

Canada's forests are important not only to Canadians, but to people worldwide. Forests help cycle water and nutrients within ecosystems and they remove carbon dioxide from the air during their growth. They provide habitat to a great variety of plants and animals, thereby protecting biodiversity. There are mounting pressures to manage these forests more effectively and sustainably. The challenge is to ensure that an environmentally acceptable method of forest management is developed while enhancing income, employment and exports for Canada. Indeed, the ability to certify that our forest products are being produced in a "green" and sustainable manner is emerging as a key aspect of market access in many world markets. The *Sustainable Forest Management Network* (SFM) was developed in response to such concerns. It is one of 20 *Networks of Centres of Excellence*, and is based at the University of Alberta. The Network supports an integrated research program to develop knowledge, strategies and tools to ensure that Canada's boreal forests are effectively managed. This research program, which is based on a 7-year strategic plan, has evolved since the inception of the Network in 1995. In the past few years, more emphasis has been placed on proposals in which interdisciplinary teams focus on integrated research projects. Thirty Canadian universities are represented in total in the Network. Over 100 researchers and 200 graduate students are involved in Network research and more than 200 graduate students have already completed their studies within the Sustainable Forest Management Network. The SFM Network has a number of funding partners beyond the federal government, including provincial governments, forest industries and First Nations.

The *Terrestrial and Riparian Organisms, Lakes and Streams* (TROLS) program at the University of Alberta completed its work in 2000. It was a collaborative effort that linked interested parties within the private and public sectors to determine the effect of forested buffers on preserving aquatic and terrestrial ecosystems during forestry operations.

The *Northern Watershed Project* is a four-year, multi-stakeholder initiative created to help government and industry understand the role of disturbances on the forest and fish resources of northwestern Alberta. Partners include the Alberta government, forestry companies, the Alberta Research Council and the Alberta Conservation Association. Its purpose is to determine the impact of human activities on fish populations and develop management strategies for forestry operations near creeks. It was completed in 2003.



Northern Alberta Wetland (AENV)

Wetlands

The *Institute for Wetland and Waterfowl Research* (IWWR) is the science and research arm of Ducks Unlimited. Its purpose is to:

- Discover new information to solve problems arising from increasing human population and reduced waterfowl habitat.
- Develop skilled professionals in wetland and waterfowl conservation biology.
- Communicate IWWR research.

Most of the research projects for IWWR deal with waterfowl habitat or specific species in southern parts of the country. Several, however, are being done in the boreal forest. One of these is on the effect of forest harvesting on waterfowl and another is on hydrology and water quality in shallow wetlands. An interesting project, which began in 2001, deals with the role of wetlands in reducing the amount of atmospheric carbon. Increasing levels of carbon dioxide is one of the causes of global warming.

Wetland Visitors (CWS, Environment Canada)

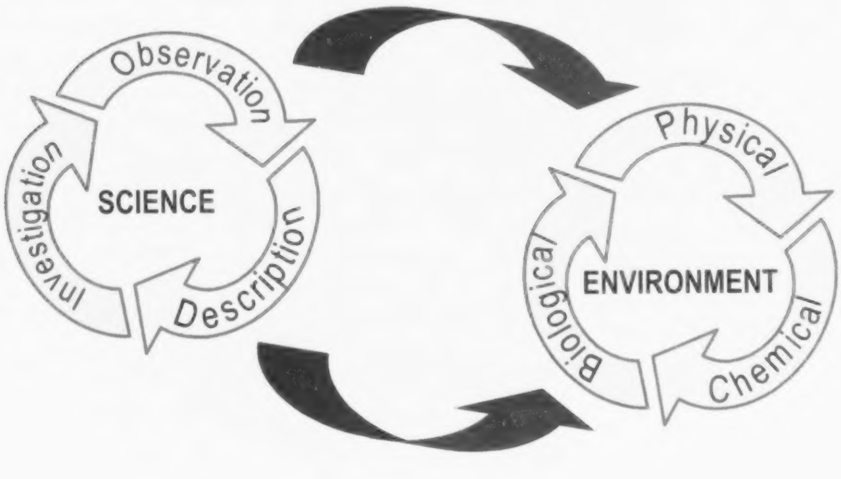
Scientific Findings

WHAT NEW INFORMATION WAS GAINED FROM NREI?

To be able to manage the northern rivers and their watersheds, we must understand the relationships among physical, chemical and biological parts of the environment. Aboriginal people understand these concepts very well, and traditional knowledge also helps us understand the environment. But to be able to say how much impact human activities have had or will have, we turn to *science*. Environmental science is simply the quantitative description and explanation of the natural world. It usually includes observation, description, experimental investigation and practical application to real-world issues.

The *Northern Rivers Ecosystem Initiative* used scientific techniques to address recommendations from the *Northern River Basins Study*. The following "stand alone" summaries of each study are grouped by general theme. As with most studies, new questions arose which should be addressed. These data gaps and suggestions for further study are presented in further detail in the technical papers, which are listed in the "References" section at the end of this report.

A variety of assessment tools were developed and used during NREI. The major ones are presented in "Environmental Models and Assessment Tools." Delta research is presented in "Hydrology and Climate" and "Ecology of the Deltas." Studies on contaminants were a major focus of the NREI – these are presented in "Contaminants." Studies on nutrients and dissolved oxygen are presented in "Other Water Quality Characteristics", and forestry issues in "Forest Biodiversity."



Environmental Models and Assessment Tools

Monitoring for environmental quality usually produces useful data, but often the data are difficult to interpret. Sometimes it is not clear why a certain measurement is different than might be expected. As well, a specific set of data on a river tells us what the river is like during the time of sampling, but does not tell us what might happen if additional human development occurs. We need tools to predict the effects of future events. And, we need ways to separate the effects of several developments. During the NREI, a variety of tools were developed or refined to address some of these issues. These include computer models, remote sensing, software programs for cumulative effects assessment, and on-site mesocosms to evaluate effects of effluents.

Scientist in Laboratory *(NWRI, Environment Canada)*

Models

An environmental model is an idealised representation of reality. It can describe, analyse or help understand the behaviour of some aspect of the environment. Usually it is based on statistical relationships among various parts of the environment. For example, in a river it was established that there is a direct relationship between inputs of nutrients in sewage effluent and algal growth on the bottom of the river – that is, the more nutrients, the greater the plant growth. A simple model might predict that if so many kilograms of nutrients went into the river, you would get "x" amount of algal growth. But the relationships among environmental factors are much more complex than this – the amount of algal growth also depends on light, flow in the river, temperature and many other factors. All of these factors can be put into mathematical equations. The basic idea is that the past behaviour of these factors can be "simulated" and predictions made of future behaviour. Once a model is set up, it has to be calibrated or verified by comparing model predictions with observed conditions in the river. So, in the above example, you could put so many kilograms of phosphorus into the model, and compare the model output with the amount of algae actually growing in the river under similar conditions.

Hydrological models tend to be more "robust" than the type of model described above. They are models that incorporate (as much as possible) physical components into the formulas. If the components are built into the model appropriately, changes in inputs will have no effect on the relationships in the model, and thus it can be very dependable and accurate. Hydrologic modelling for the entire northern rivers basin, however, is a combination of physically based formulas along with observed relationships. Therefore, a model like this requires some calibration.

Impact of Land Use on Water Balance and River Discharge

R.J. Granger, N. Hedstrom and T. Brown

One of the recommendations of the *Northern River Basins Study* was to make sure that land use planning and water use planning are integrated. The fate of river ecosystems is critically dependent on what happens on the land. An integrated assessment of various land uses on stream flows is necessary to make sound recommendations for improved land management practices.

The purpose of the Cold Regions Hydrological Model is to provide the water resources practitioner with a scientific tool consisting of well-defined techniques to calculate the runoff contribution from various land surfaces. The model is designed to be sensitive to land use and climate changes. It can be used to assess the impacts of these changes on the hydrological state of a watershed as indexed by soil water supply, stream flow, etc. It is relatively easy to update and improve as new research results become available.

The model can be used to evaluate the impacts of land clearing, land conversion, natural burn and re-vegetation on the hydrology of watersheds. It is through the hydrological pathways (on the land, under the soil and in the waterways) within the basin that the impacts of land use changes will be transferred to the aquatic ecosystem. Understanding the impacts of land use change is therefore largely dependent on how well we understand these hydrological pathways and how they respond to the changing land surface.

The model framework permits simulation of hypothetical land use changes within river basins by "virtual clear-cutting" of portions of the watershed. As well, it allows us to assess the impacts of these changes on the hydrology of the basin. Conversely, we can also assess improvements to land management practices and provide flow volumes for predictions of instream flow needs for aquatic life and transport of nutrients and contaminants.

The model was tested with data from the Upper Paddle River basin in northern Alberta. We compared the modelled and observed snow accumulation and basin runoff. We found that the Cold Regions Hydrological Model gives a realistic assessment of the basin water balance, or the water balance for specific parts of a basin. We ran the model for various land use scenarios, such as the conversion of forested lands to agriculture. The model runs showed that converting 30% of the basin area from forested to agricultural and pasture lands results in an increase in the basin snow melt water, and a near doubling of the basin runoff. Figure 10 shows runoff per unit area for a variety of land use types. This shows that the agricultural, pasture and riparian land surfaces produce a much higher runoff than forested land. It is quite evident then, that modifying the relative proportions of these land covers within a basin could have a significant effect on the total runoff from the basin. In turn, this would affect the amount of flow in streams.

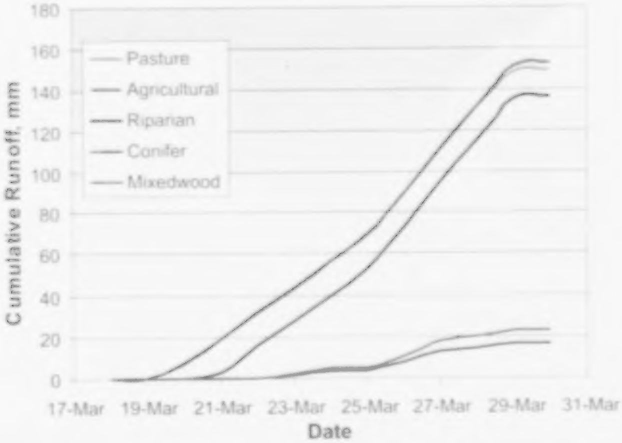


Figure 10. *The relative contributions of runoff in millimetres from the various land types within the Upper Paddle River basin for the test period in 1999.*

Land Cover Classification

Alberta Ground Cover Characterization Project Summary 2002

G.A. Sanchez-Azofeifa, S. Hamilton, M. Kachmar and S. Rudyk

It is becoming increasingly important to assess land cover on a regional scale to provide a tool to balance conservation and development issues. The *Alberta Ground Cover Characterization* project began in 1999. Its purpose was to produce a land cover map for the Northeast boreal forest region of Alberta. We used Landsat 5 TM imagery to extract land cover information for an 11 million hectare area in the northeast corner of the province. The ground cover from the satellite images were classified into broad categories, such as open/closed forest, shrubland and wetlands, and into more detailed sub-categories, such as conifer, deciduous, bog, etc. Then, a helicopter was used to verify or "ground truth" the satellite data. This allowed plant species to be identified and the amount of canopy recorded. The map produced represents a large area on a small scale. It incorporates forest species information as well as natural features such as watercourses, rock and sand dunes.

Remote Sensing

Monitoring Delta Ecosystem Response to Water-Level Restoration

A. Pietroniro and J. Töyrä

The Peace-Athabasca Delta is large, nearly 100 km wide and long, with unique terrain. Detailed and accurate topographic information was lacking, as was information about the movement of water. As a result, we decided to use remote sensing as a hydrological monitoring tool. The objective was to use remotely sensed data along with ground-based observation to provide an efficient monitoring strategy that supplements traditional monitoring methods. Although remote sensing may not provide the high level of detail obtained by usual sampling methods, it does allow for spatial snapshots of the entire delta over time.

Remote Sensing

Gathering information with the use of a device that is distant from the object of study, such as from an aircraft or satellite. Devices such as cameras, lasers, radar systems and infrared detectors are typically used.

A combination of Radarsat Synthetic Aperture Radar (SAR) and visible-infrared satellite images was used to generate flood maps. SAR is useful for flood mapping because it is sensitive to differences in moisture. It is also able to penetrate clouds and vegetation. The general vegetation patterns in the Delta were mapped using multi-temporal SPOT-4 images. The topography in seven areas was surveyed using airborne scanning LiDAR (Light Detection and Ranging). LiDAR data were used to generate a Digital Elevation Model of selected non-flooded areas.

Cumulative Effects Assessment

Development of a Cumulative Effects Assessment Framework for Aquatic Ecosystems

M. Dubé, J. Culp, K. Cash and K. Munkittrick

Sustainable development of aquatic environments means that development occurs at a rate that rivers and lakes can tolerate so they can be used and enjoyed by future generations. To decide if we are developing in a sustainable way, we need to know the impacts from all of the developments on a river or lake, and what the impacts from future development will be. We also need to know how healthy our waters are and if they are tolerating development. Stressors may include anything that could change the natural state – industrial and municipal discharges, agricultural runoff, forestry operations and/or urban land use. All of these can add up and cause harmful effects on the quality of the water and the health of fish, invertebrates and plants. We also need to know how climate cycles, and how changes in water flow affect these impacts. Cumulative environmental effects are the changes to the environment from a human activity in combination with other past, present and future activities.

Cumulative Effects Assessment (CEA) is a process to assess how all stressors are impacting on an aquatic system and if the system can tolerate new development. In theory, it is a running tally of river and lake health and development and it can be applied at local, watershed, and regional scales. In practice, CEA is so complicated that we have yet to develop methods to measure it in a way that makes sure that development is sustainable.

One approach to CEA (called *project-based CEA*) focuses on a proposed development. All of the stressors that the project may generate are identified. Then it is determined how each stressor will affect the environment by itself or in combination with other stressors. This approach is most commonly used in the Canadian Environmental Assessment process for new project developments. The limitation with this approach is that the emphasis is on the project and its stressors with little emphasis on measuring the health of the waters to see if it can tolerate more development. This approach is generally used at local scales. Often, impacts may seem unimportant at a local scale but very important when measured at larger scales.

The other approach to CEA, called *regional-based CEA*, measures the response of the aquatic environment to cumulative stress. It occurs over local to regional scales and works in reverse of project-based CEA. The condition of the water is measured first and if impacts exist then the process works back to identify which stressor is causing the impact. These methods were used in the national *Environmental Effects Monitoring Program* and to some degree in the *Northern Rivers Basin Study*. The limitation with this approach is that a stressor is identified after an impact has occurred. For CEA, it is important that we can predict impacts before they happen. Both project-based and regional-based CEA approaches are required to achieve our goals for sustainable development. We need to be able to measure if an aquatic system is "stressed" and by how much. We also need to be able to predict if a new project development will cause the system additional and unacceptable stress.

We developed a CEA framework for aquatic systems in which the strengths of both approaches are integrated. The framework envisions a regional aquatic "weather station" where information from many different agencies is integrated and evaluated on an on-going basis to identify areas of poor to excellent aquatic health. This would include present and new development, water flow, water quality, health of aquatic life, etc. If new developments are being proposed, the developers and the regulators could use this information to see if the waters in the area can tolerate more development. If developers collect information on aquatic health, this information would be added to the "weather station" database before and after development to measure any impacts.

Implementation of a Cumulative Effects Assessment Framework for Northern Canadian Rivers Using Decision Support Software

M. Dube, J. Culp, K. Cash, K. Munkittrick,
B. Johnson, J. Inkster, G. Dunn,
B. Johnston, W. Booty, I. Wong, D. Lam,
O. Resler and A. Storey

Following from the CEA framework (*discussed above*), we developed an innovative new tool to assess cumulative effects. This tool is like a regional, science-based aquatic "weather station" – information from many different agencies is integrated and evaluated on an on-going basis to identify areas of poor to excellent aquatic health. The information might include such things as development, water flow, water quality, fish and aquatic insects.

Regulators, industry, scientists, First Nations, and the public could use this information to determine the health of waters in a specific area of their interest. The information could also be used to determine if levels of development on a broad scale are proceeding according to planning targets for sustainable development.

In practice, the aquatic "weather station" uses a multi-component software tool called EcoAtlas-CE (cumulative effects). It contains:

- EcoAtlas, a map-based geographic information system that displays and graphs aquatic data available at each sampling site.
- The Environmental Effects Monitoring Statistical Assessment Tool, a program that automatically analyses biological data (fish and benthic invertebrates). It can show if effects exist at a site, whether they are greater or less than at a reference site, and the magnitude of any effects.
- The EcoAtlas Water Quality Index Calculator, a program that calculates a variety of water quality indices to rate water quality in an area from poor to excellent. The results of the biological and water quality assessments are displayed in EcoAtlas-CE to illustrate an "accumulation" of effects.

We used EcoAtlas-CE to conduct a cumulative effects assessment for the Athabasca River. It showed changes in water quality and organisms along the river from the headwaters near Jasper down to the mouth at Old Fort. Development of the software provided an opportunity to examine ways to improve the way we monitor our rivers and better integrate knowledge. It also illustrated how large volumes of information can be summarized to show if changes are occurring and what may be causing those changes. This integrated knowledge is essential to make sure our resources are being developed in a sustainable way for future generations of Canadians.

Mesocosms

Mesocosm Assessment of Pulp Mill and Municipal Sewage Effluent Effects on Benthic Food Webs and Longnose Dace (Rhinichthys cataractae) of the Wapiti River, AB

J. Culp, M. Dube, K. Cash, N. Glozier,
D. Maclatchy and B. Brua

Standard environmental effects monitoring (EEM) for the evaluation of fish and their food (benthic invertebrates) generally focuses on field collections. Field monitoring can provide important insights into the response of aquatic plants and animals exposed to multiple effluents. But these techniques typically do not allow researchers to identify the effects of various substances in the effluents. An alternative tool is to use mesocosms. These are tanks or containers set up on shore, through which river water and measured amounts of effluent can be pumped.

The mesocosm approach is scientifically rigorous – experiments can be done over and over, and one or more of the treatment containers are left untreated as controls (conditions simulating the river upstream of effluents). Plants and animals from the nearby river can be added, and the response to each treatment measured. Characteristics measured may include the quantity of algae, abundance and species of invertebrates, and fish survival and growth (*see more information on p. 97*).

Mesocosm Technology: Large Systems (Environment Canada)

Hydrology and Climate in the Delta Area

Deltas of major rivers are among the most productive and environmentally sensitive components of river systems in cold climates. They are particularly sensitive to changes in yearly water flow patterns, which can produce changes in the transport and deposition of sediments. The *Northern River Basins Study* (NRBS) found that climate change, in addition to flow regulation at the W.A.C. Bennett Dam, might be a factor in changing the hydrology of the Peace River and the deltas of the Peace, Athabasca and Slave rivers (*Figure 11*). The NRBS recommended research to address the interactions among climate, hydrology and the environment. NREI scientists looked at the effects of climate and other environmental factors on the Peace-Athabasca and Slave rivers and their deltas. Some of the insights gained from these studies are described in the following section.

Flood and Vegetation Mapping

Monitoring Delta Ecosystem Response to Water-Level Restoration

A. Pietroniro and J. Töyrä

The ecology of the Peace-Athabasca Delta is driven by its hydrology. In the past, scientists thought that reduced flooding and declining water levels would allow willows to advance into the wetlands and replace the existing vegetation, mostly grasses. On the other hand, it is possible that the wetland ecology is much more resistant to change than was previously believed. Although there is considerable scientific debate about the role water plays in the vegetation patterns, it was clear that an effective way to assess these changes was needed.

This research focussed on mapping the extent, frequency and duration of flooding and vegetation patterns in the Delta. Detailed and accurate topographic information was lacking, as was information about the movement of water. The objective was to use remotely sensed data along with ground-based observation to provide an efficient monitoring strategy that supplements traditional monitoring methods.

Flood Mapping. We used a combination of Radarsat Synthetic Aperture Radar (SAR) and visible-infrared satellite images to generate flood maps for the six-year period between 1996 and 2001. SAR is useful for flood mapping because it is sensitive to differences in moisture. It is also able to penetrate clouds and vegetation.

The delta was subjected to major overland flooding in the spring and summer of 1996 and in the spring of 1997. During the following years, the delta went through a drying trend with receding water levels. The drying trend can be followed on the flood maps from May 1998 to July-August 2001 (*Figure 12*). These maps clearly depict the extent of the 1996 and 1997 overland floods (on the May 1998 map) and the subsequent water level decline. The open water and flooded vegetation classes were reduced in size

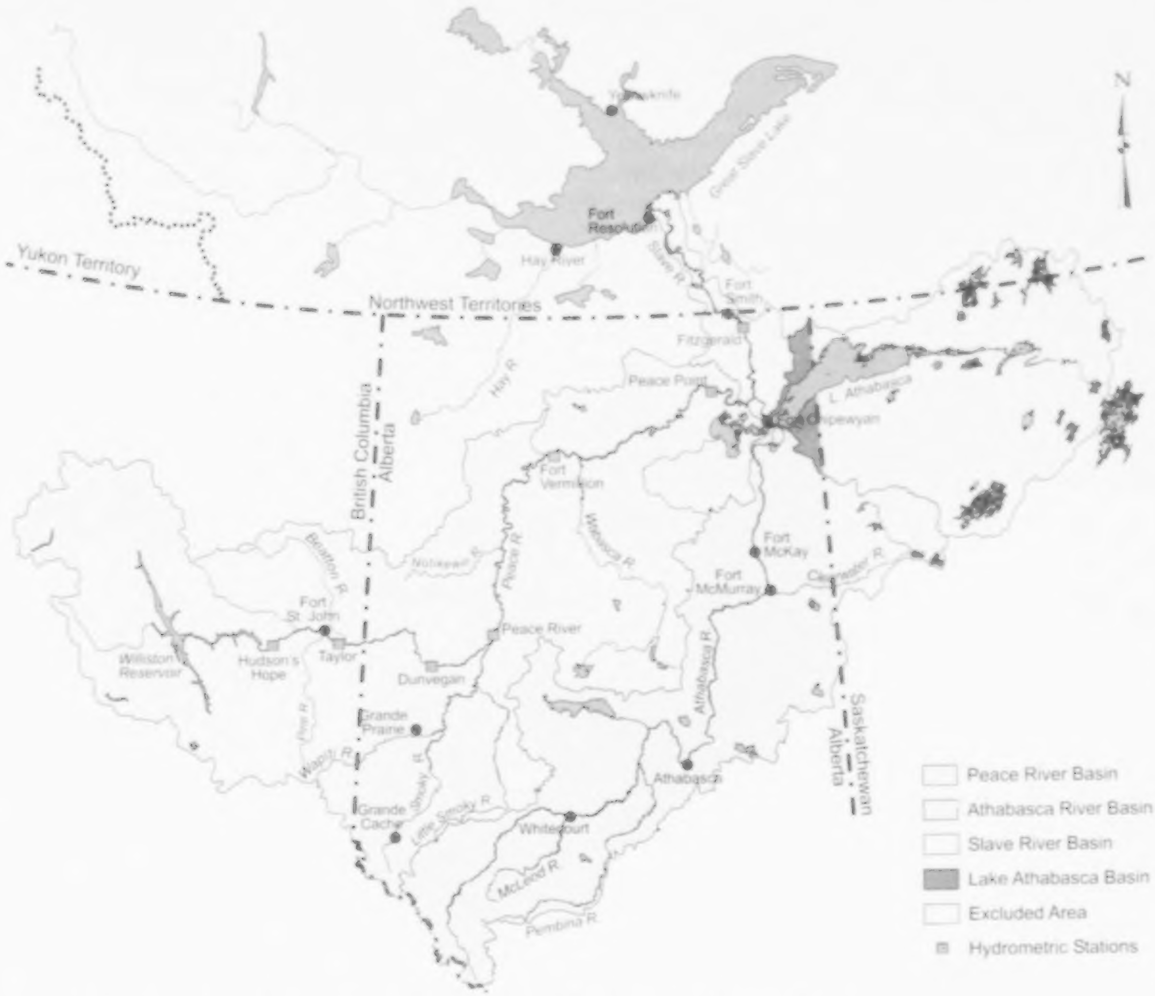

N
Yellowknife
Great Slave Lake
Fort Resolution
Hay River
Slave R.
Fort Smith
Yukon Territory
Northwest Territories
Fitzgerald
Peace Point
L. Athabasca
Fort Chipewyan
British Columbia
Alberta
Hay R.
Fort Vermilion
Wabasca R.
Fort McKay
Fort McMurray
Clearwater R.
Beatton R.
Notikewin R.
Peace R.
Fort St John
Williston Reservoir
Hudson's Hope
Taylor
Peace River
Dunvegan
Athabasca R.
Saskatchewan
Alberta
Grande Prairie
Pine R.
Wapiti R.
Smoky R.
Athabasca
Grande Cache
Little Smoky R.
Whitecourt
McLeod R.
Pembina R.
Peace River Basin
Athabasca River Basin
Slave River Basin
Lake Athabasca Basin
Excluded Area
Hydrometric Stations

Figure 11. *Watersheds of the Peace, Athabasca and Slave rivers.* (Environment Canada)

toward the end of this period. The levees emerged and many basins became isolated from the drainage network. Because evaporation is higher than the amount of precipitation in the Peace-Athabasca Delta, the water in the isolated basins was lowered by an average of 90 mm per year.

The flood duration maps show that the rivers, lakes and many of the wetland basins became isolated as the floodwater receded. Many of these basins were mapped as having water for all six study years. Figure 12 also highlights the levees and other elevated sections that did not flood at all or only flooded for a short period. Such maps are invaluable for detecting any ecological change.

Vegetation Mapping and Topography. The general vegetation patterns in the Delta were also mapped using multi-temporal SPOT-4 images from the summer of 2001. By comparing the vegetation and flood duration maps, we could look at the relationship between vegetation patterns and duration of flooding. The focus of vegetation mapping was directed toward outlining the extent of willows in the Peace-Athabasca Delta. The vegetation mapping was limited to the centre portion of the delta, because the field sampling on the ground was focussed in this region. This area was selected because it includes an active portion of the deltas in Mamawi Lake, many isolated and open wetland basins, and higher levees. This allowed us to evaluate the relationship between vegetation and elevation. The May 2001 and August 2001 remote images that were used for the flood mapping were also used for the vegetation mapping.

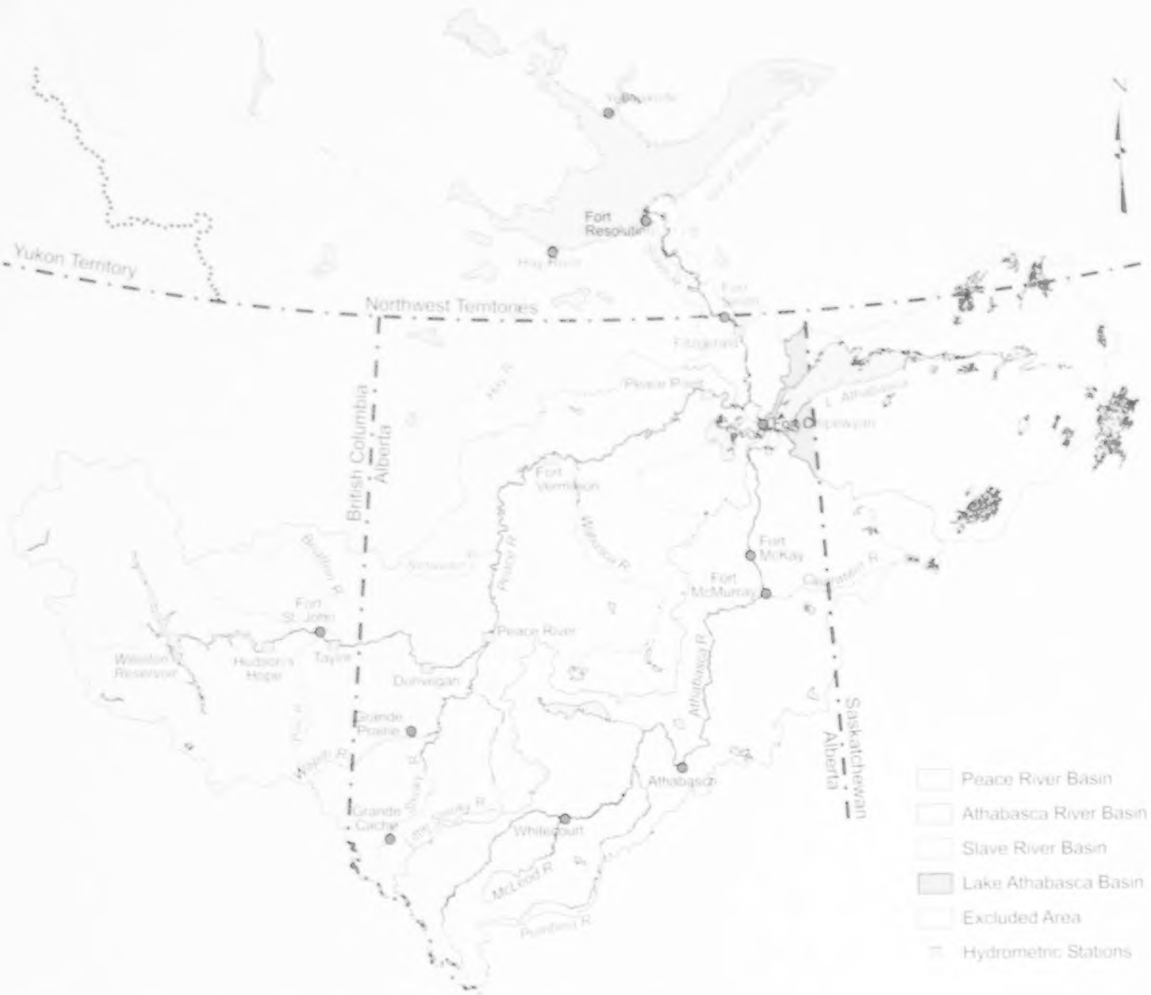

Yellowknife
Fort Resolution
Hay River
Yukon Territory
Northwest Territories
Fort Smith
Fitzgerald
Peace Point
L. Athabasca
Fort Chipewyan
British Columbia
Alberta
Fort Vermilion
Peace R
Wabasca R
Fort McKay
Fort McMurray
Clearwater R
Fort St. John
Peace River
Williston Reservoir
Hudson's Hope
Taylor
Dunvegan
Grande Prairie
Wapiti R
Smoky R
Athabasca R
Athabasca
Saskatchewan
Alberta
Grande Cache
Little Smoky R
Whitecourt
McLeod R
Pembina R
Peace River Basin
Athabasca River Basin
Slave River Basin
Lake Athabasca Basin
Excluded Area
Hydrometric Stations

Figure 11. *Watersheds of the Peace, Athabasca and Slave rivers.* (Environment Canada)

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The topography in seven areas was surveyed using airborne scanning LiDAR (Light Detection and Ranging). We used airborne scanning LiDAR data from the summer of 2000 to generate a Digital Elevation Model of selected non-flooded areas. The LiDAR accuracy was satisfactory and the elevation model proved to be quite detailed and useful for understanding the subtle topographic patterns in this relatively flat region. We compared the vegetation map to the elevation model and were able to see a relationship between vegetation patterns and topography. Because these spatial databases proved useful, we suggest that flood and vegetation maps should be made annually to monitor the changes that occur in the delta.

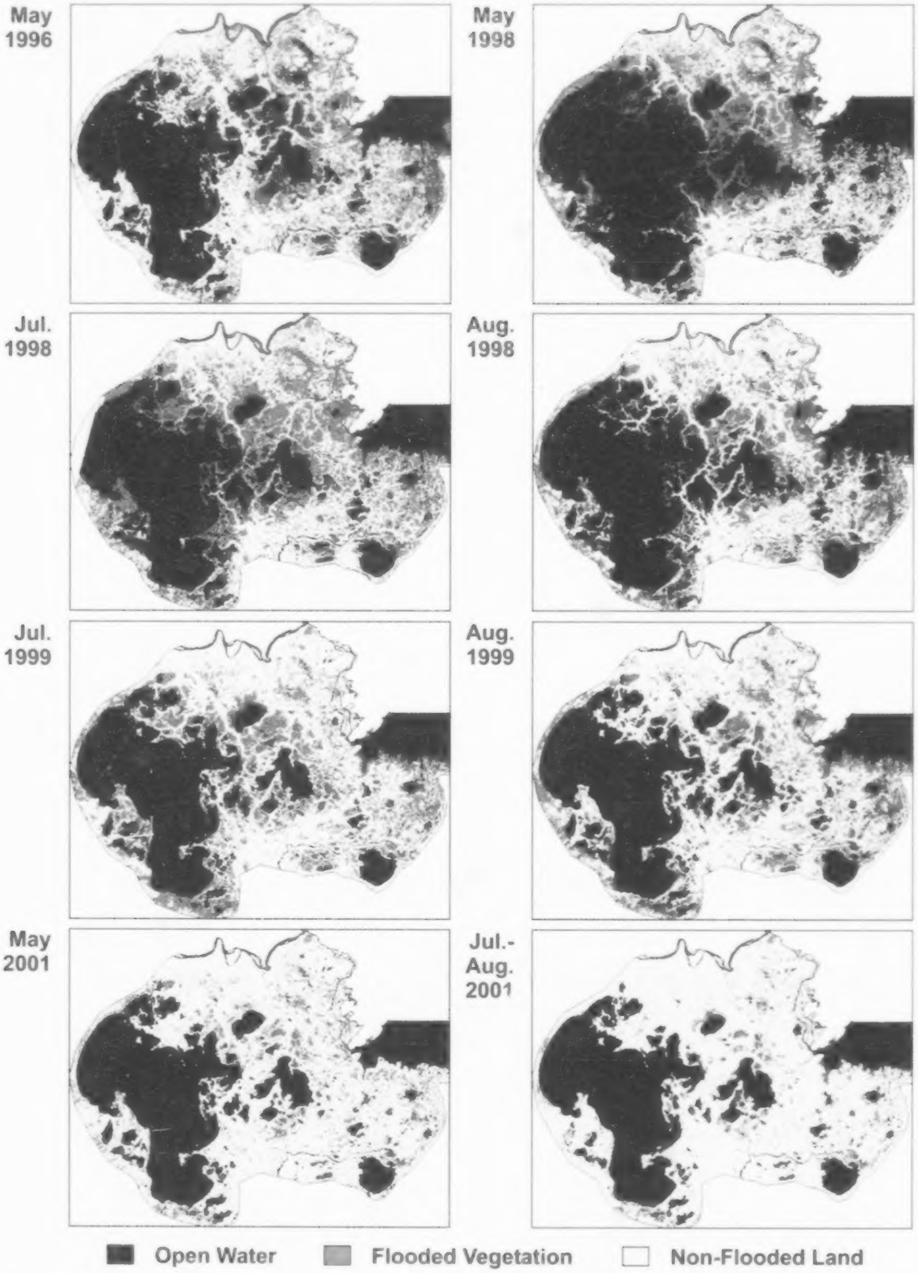

May 1996
May 1998
Jul. 1998
Aug. 1998
Jul. 1999
Aug. 1999
May 2001
Jul.- Aug. 2001
■ Open Water
▨ Flooded Vegetation
☐ Non-Flooded Land

Figure 12. *The Peace-Athabasca Delta flood maps generated by radarsat SAR.*

The study showed that the data generated were very useful in discovering delta-wide relationships. Satellite remote sensing affords the only reliable means of assessing flood extent in this region. If these maps were done annually, they could form the basis of an ecological monitoring program for the Peace-Athabasca Delta. The scanning LiDAR technology provided relatively accurate, very useful and highly detailed topographic information.

Impacts of Climate Change

Hydro-climatic Impacts Affecting the Peace-Athabasca-Slave Catchments and Deltas

T.D. Prowse, S. Beltaos, B. Bonsal,
T. Carter, M.C. English, T. Gardner,
J.J. Gibson, D.L. Peters and L. Romolo

The following Northern Rivers Ecosystem Initiative studies were designed to look at hydro-climatic impacts on the Peace-Athabasca Delta and its basins, and the Slave River Delta.

The results described below outline the major effects of hydrology and climate change on the Peace-Athabasca and Slave River deltas over the available historical record. In the future, flow regulation at BC Hydro's W.A.C. Bennett Dam could potentially be used to offset the effects of climate change.

Peace-Athabasca Delta. The original concern that initiated the hydrologic studies of the NRBS was that the Peace-Athabasca Delta was drying, especially the many small lakes and ponds called perched basins (*Figure 13*) that surround the major delta lakes. We assessed the origins of drying and flooding through the historical record and assessed future conditions under a changing climate. As well, we evaluated flow regulation as a potential means to offset the effects of climate change.

During the NRBS, a water-balance model was developed to explain the origin, fate and persistence of water held in the numerous perched basins within the Peace-Athabasca Delta. This model was improved during the NREI to make it work more realistically. The perched basins lose water mainly through evaporation, and regain water when the rivers flood and overtop their banks. The updated modelling results indicated that the basins typically dry out in five years during cool, dry periods and in nine years during wet periods. They will dry out even more rapidly as the climate changes.

Future climatic conditions for the period 2070 to 2099 were also evaluated with a Canadian climate change model. Results showed that the ice season would be reduced by three weeks (one week in the autumn, two weeks in the spring), which would extend the open-water season and permit greater evaporation.

Environmental Model

A model is a tool that re-creates an event in nature. Because models are complicated, a computer is usually used. They use equations that were formulated through testing under natural conditions or are based on scientific theory.

A computer program is developed, and new data entered. The program is run, and then the results ("output") are compared with conditions actually in the environment ("observed"). If the model output is similar to the observed, new data can be entered and reliable predictions made.

This extended open-water period, combined with higher air temperatures (an increase of 4°C near Fort Chipewyan), was forecast to increase evaporative loss of water by about 35%. Despite projected increases in precipitation (by about 11%), the enhanced evaporation will lead to more rapid drying and thus, an increased dependence on flooding to avoid prolonged drying of the perched basins.

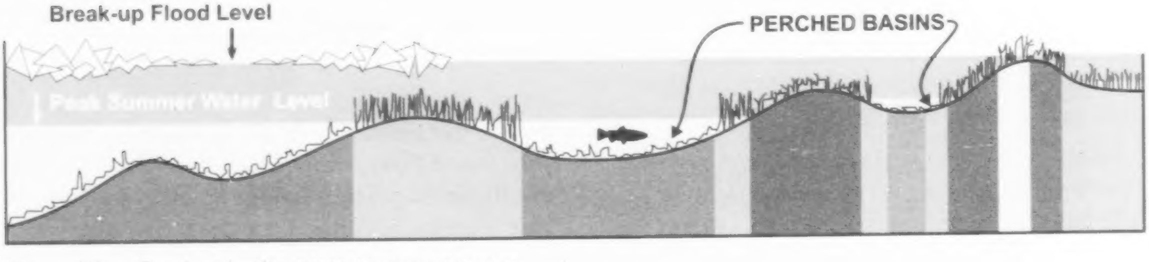


Figure 13. *Perched basins (NWRI, Environment Canada)*

Another part of the study looked at open-water and ice-jam flooding events. High water levels capable of flooding the delta landscape are relatively common near the Athabasca Delta but are virtually non-existent along the Peace River.

The effects of flow regulation were separated from climatic effects in the models used. The recorded data show that the highest open-water flow on the Peace River occurred in June of 1990. Model results indicated that flows would have been even higher without the effect of flow regulation by the W.A.C. Bennett Dam – resulting in a higher flood peak for that event. According to the model, another very high open-water flood peak would have occurred in June of 1972, if the river had not been regulated. Results suggest that these flood peaks would have been much greater than any other flow observed, before or after regulation. They would have been in the range of flows capable of producing direct overbank flooding of the northern edge of the Peace Delta. Analyses found that flow from the alpine headwaters help to create these open-water flood peaks. Since regulation, however, storage of much of this upstream flow during the summer months reduces the amount of water that could contribute to flooding.

Another source of perched-basin flooding is high water levels in the large delta lakes. Water levels in Lake Athabasca (and in the related delta lakes) have generally been lower when compared to simulated, naturalized water levels, but on occasion have also been higher. The pattern of year-to-year peak water level variation is similar between the regulated and naturalized levels, suggesting that the hydro-climatic conditions within the unregulated portions of the contributing basins have a strong influence on summer lake levels.

In general peak water levels have been reduced because flow reversals from the Peace River into the delta lakes have been fewer in frequency and magnitude. On average, the total volume (cubic metres per second) and duration (days) of flow reversals into the delta from the Peace River has been reduced from approximately 22 000 from 1960-67 (before the dam was built) to 3000 (m^3/s) from 1972-96 (after regulation).

Ice jams are the most important source of overbank flooding. This flooding is largely dependent on tributary flow downstream of the dam. Large events are associated with large snow packs on tributaries such as the Smoky River. Although snow packs were low from the mid-1970's until the mid-1990s, the trend toward lower winter snow packs was disrupted in the late 1990s. In 1996, a large snowmelt runoff helped generate a major ice-jam flood in the Peace-Athabasca Delta. The conditions that characterized this ice-jam flood were investigated. During this event, BC Hydro followed a recommendation of the NRBS final report and released additional flow to the Peace River during the period that an ice jam was developing. This flow addition elevated the flood level at the delta by about 0.27 m at its peak effect.

Dry and Wet Conditions in a Perched Basin
(Environment Canada)

Results of ice-jam modelling studies indicated that a flow of approximately 4000 m^3/s is required to produce overtopping of the Peace River banks and subsequent flooding of the delta. Major floods required a total winter snow pack of at least 150 mm and intense spring heating to generate a large ice-jam flood.

Future climate scenarios, for the period 2070-2099, suggest that mid-winter thaws of the winter snow pack would likely occur, but this would be insufficient to produce enough runoff to generate large ice jams. In spring, there could be a 15% reduction in ice thickness and an advance in spring warming, so that breakup would occur earlier. Most significantly, however, ice-jam flooding is forecast to be less frequent and severe because of reduced winter snow packs – partly because of increased winter rainfall instead of snow.

Slave River Delta: Much less is known about the Slave River Delta compared with the Peace-Athabasca Delta. The studies under NREI attempted to target both climate and flow-regulation issues in the Slave River Delta. To obtain an historical hydrologic picture of the delta, flow pattern changes were documented. Because some of the most biologically productive areas are found beyond the apex of the delta, a special focus was placed on hydrologic conditions in this area and on interactions between the delta and Great Slave Lake.

We constructed a water balance for Great Slave Lake, the largest lake along the Mackenzie drainage (*Figure 14*). An important reason for doing this was to assess the potential impacts of changing lake levels on the structure and function of the Slave River delta, including deposit of sediments. We examined the potential sensitivity of the system to climate and water resources impacts over the past 35 years, including the influence of Peace River flow regulation that began in the late 1960s.

Three-fourths of long-term inflows to Great Slave Lake originate from the Peace-Athabasca-Birch-Fond du Lac watersheds situated far to the south, which enter the lake via the Slave River (*Figure 14*).

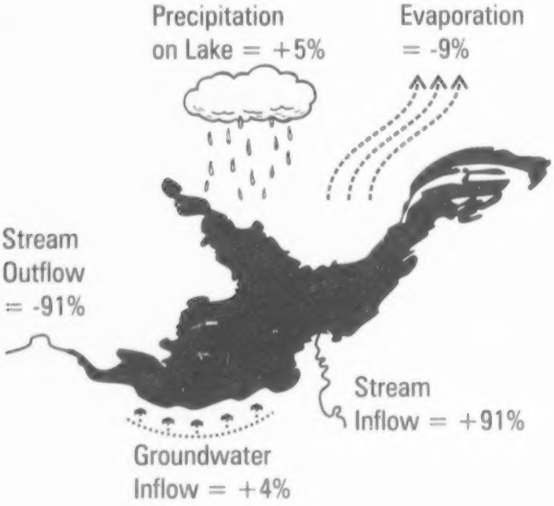


Figure 14. *Water balance of Great Slave Lake, 1964-1998. (AENV)*

Approximately 20% of the water comes from areas bordering Great Slave Lake, while 5% is derived from precipitation onto the lake surface. Inflows and outflows are the over-riding control on long-term water levels in Great Slave Lake. Lake levels during 1964 to 1998 fluctuated within a range of about 1.1 m. The lowest water levels were observed during periods of dry conditions (1980, 1981, 1995) in the Peace-Athabasca basins. Similar lows were observed during filling of the Williston Reservoir in the 1968-1972 period. Lake levels fluctuate by 0.5 m or so during typical yearly cycles although such changes could be more rapid. For example, during November 1995 to August 1996, lake levels rose by over 1 m in response to heavy precipitation and additional water releases from the Williston Reservoir.

In an effort to assess the relative effects of climate versus regulation, a water balance model for Great Slave Lake was used along with naturalized flow simulations to approximate conditions had there been no regulation in this system. Evaluations of the regulated flows (1972-1996) compared to the pre-regulation flows (1938-67) indicated that the amplitude of the water level variations has been reduced by 0.11 m along with a decline of 0.12 m in mean maximum water levels. Moreover, water level peaks tend to occur earlier.

The comparison of pre-regulated with naturalized (regulated) flows suggest that there have also been climate-driven effects. Results indicate that the amplitude of the water level fluctuations and mean maximum water levels would have increased. Peak water levels would also have occurred earlier, but to a lesser magnitude.

Comparison of the these modelling results indicate that climate and regulation impacts have generally counter-balanced each other, in terms of changes in the amplitude of water level fluctuations and magnitude of peak water levels. In addition, they have cumulatively contributed to the occurrence of earlier peak water levels on Great Slave Lake.

To evaluate the potential effect on the delta of changes in water levels of Great Slave Lake, it was necessary to establish how far inland such water levels could intrude into the Slave River Delta. Because there were no slope data for the delta, we conducted extensive field surveys along a western tributary of the delta. Results of the surveys indicated that a very low slope (approximately 7-15 mm/km) characterized the zone from the outer delta to 14 km upstream, at about the first major branching of the Slave River. A lake level rise of 10-20 cm is sufficient to affect the flow and sediment deposition up to the main entry point of the river. The difference in water level between wet and dry years is larger than this amount, as are seasonal changes in water level produced by flow regulation. Hence, both effects have the potential to alter large areas of the main active delta. Another natural condition that was identified as a strong potential modifier of delta processes was wind. Strong winds push the lake water toward the downwind side. This is called a *seiche*. Large seiches appear to be capable of producing 30-50 cm increases in water level at the outer delta perimeter. Increases of this scale are a potential source of flooding of the outer delta.

The Slave River Delta, like the Peace Athabasca Delta, had apparently experienced some drying effects before NRBS began. The overall flow pattern (channels) from 1946 to 1960 appeared relatively static with the main flow path through the central delta. In 1966, when flows were lower and lake levels decreased, there appeared to be a major shift eastward to the Resdelta channel. By 1973, after the Bennett Dam was in place, the shift in flow to the Resdelta (East) channel was complete and the western and southern portions of the delta were drying.

Athabasca River at Hinton (AENV)

Basin Runoff

Modelling Climate Change Impacts on Water Availability in the Peace Athabasca Catchment and Delta

A. Pietroniro, F.M. Conly, B. Toth,
R. Leconte, N. Kouwen, D.L. Peters
and T.D. Prowse

During the NRBS, it was noted that both climate change and operation of the WAC Bennett dam might affect the hydrology of the Peace River, the Peace-Athabasca Delta and the Slave River Delta. The Peace and Athabasca rivers directly affect the composition and availability of wildlife habitat of the Peace-Athabasca Delta. To investigate this further, we used hydrological and hydraulic models to assess the relative roles of climate change and flow regulation on the runoff characteristics of the Peace-Athabasca drainage basin and the delta region.

The physical principles used in these models are well known: water falls on the ground as precipitation and runs off or moves through the soil and collects in channels, and eventually reaches tributaries and finally the rivers. Yet, there is still much uncertainty in the ability to predict precisely the magnitude and timing of stream runoff. Also, because actual observations for the area are scarce, we cannot accurately determine how wet or dry a region is at any given time. Therefore, we used historical temperature, precipitation and runoff data to fine-tune our ability to simulate what is happening in the streams and rivers. All model simulations of historical data were compared against observed stream flow. When acceptable simulations were achieved, we then re-ran the model using future potential climates to assess impacts. The models predict that annual average temperatures will increase by 1°C to 4.5°C, which stem from a doubling of carbon dioxide concentrations in the atmosphere.

To simulate present flows in the Peace-Athabasca basin, the model was run for a 24-year period, 1965 - 1989, and then future flows under higher temperatures were modelled for 2040-2069. For the Athabasca and Peace rivers, spring melt is expected to begin earlier. The total annual volume of flow is predicted to increase under the increased temperature and precipitation of a future climate. Much of this increase will occur during the winter. The increase in runoff is expected to be greater from low elevation areas and wetlands of the Athabasca River, but this increase dissipates toward the Delta. The high elevation and mountainous basins of the Peace River also are expected to have higher runoff. But with higher temperatures, evaporation increases so that flows in the rivers may actually decrease. In low-flow years, levels in the Peace River could peak as much as two months earlier than at present. During high-flow years, the peak level could occur 20-30 days earlier. These changes could affect the frequency and severity of ice jams and therefore the replenishment of the small lakes and ponds in the Peace-Athabasca Delta.

Of particular concern is the prediction of lower summer water levels in the Peace and Athabasca rivers. These decreases could amount to as much as 0.5 m in the Peace and 0.2 m in the Athabasca, for many of the years simulated. This is significant as navigation and other uses may be jeopardized.

It was not possible to predict with any certainty the effect of a changing climate on inflows to the Williston Reservoir, although model predictions suggest that total annual inflows may not be altered significantly. The timing of inflows over a year, however, may be quite different. Future scenarios suggest that inflows may be higher than at present between October and April, but lower between May and July.

A winter severity analysis, based on present open-channel flow conditions, showed that a mild winter (shorter ice season) reduces the maximum water level in Athabasca, Claire and Mamawi lakes. Varying ice seasons results in water level fluctuations of about 10 cm above or below current conditions for Lake Athabasca and 5-8 cm in Claire and Mamawi lakes. A severe winter with a long ice season would maintain high water levels and a shorter ice season would generate low water levels in the lakes. Flow reversal into Lake Athabasca, such as the one that occurred during the high flood associated with ice jamming in the spring of 1972, is significantly affected by the duration of ice period. An increase in water levels in the major lakes lasts for some months, while water levels in the river systems increase for a short period around breakup.

Water levels in the major lakes in the Delta may be affected by climate change, although different models produce different results. High winter flows in the rivers may cause the ice on the lakes to melt earlier. As well, the highest elevation in the lakes will occur earlier in the year than at present. In general, a shorter ice season due to earlier melt will result in lower lake levels.

Peace River near Fort Vermilion (AENV)

Ecology of the Deltas

The Peace-Athabasca and Slave river deltas are particularly sensitive ecosystems. The deltas provide homes for a great variety of birds and mammals, and they are regionally important sources of fish. There was a drying trend from 1975-96 in the Peace-Athabasca Delta. Flooding in 1996 and 1997 was followed by another period of drying, which has continued to the present. Climate change and impacts from human activities may be affecting these internationally significant areas. The NREI looked at several aspects of the ecology of the deltas, including indicators of possible change and birds in the delta. These studies are presented below.

Indicators of Ecological Integrity

State of the Aquatic Environment - Peace-Athabasca Delta - 2002

D. Donald, W. Aitken, J. Syrgiannis,
N. Glozier, F. Hunter and M. Gilchrist

The ecological integrity of the Peace-Athabasca Delta is threatened by activities that occur upstream of the Delta. These include industrial and municipal effluents, climate change, forestry, development, hydroelectric operations, atmospheric pollutants, and renewable resource use. We identified environmental indicators to provide Parks Canada, resources managers and pollution control officers within the Peace and Athabasca river basins with information on the ecological integrity of aquatic ecosystems within the Delta. An important goal of resource managers and basin residents is to maintain the ecological integrity of the Peace-Athabasca Delta for future generations.

For the Peace-Athabasca Delta we define ecosystem, ecological integrity, and ecosystem indicator as follows:

- An **ecosystem** is an interacting dynamic and complex system of living and non-living parts linked by the cycling of materials and the flow of energy.
- **Ecological integrity** is the maintenance of the structures and function of the Peace-Athabasca Delta ecosystem unimpaired by human stressors. This means that native plant and animal species should remain at historic population levels and with sustained harvest (but not exploitation) of renewable resources by people. People are both indigenous to and an important ecological link in the Delta ecosystem.
- **Ecosystem indicators** are aspects or parts of an ecosystem that are measured to assess ecological integrity. These can also be used to determine if environmental goals are being met. The identification, selection and use of ecological indicators is a social, economic, and scientific exercise that follows the general model outlined in Table 6.

Table 6. *Development and use of ecosystem indicators. Moose are used as an example.*

	Responsibility	Examples
Objective	Social/ economic	Maintain ecological integrity of moose habitat
Indicator	Social/ scientific	Maintain moose population at 1/km^2
Measurement	Scientific/ technical	Count moose or moose pellets
Remedy Adjustment	Senior-Management/ technical	Prescribed burn to increase habitat for moose

During this study, seven ecosystem indicators were used to evaluate the status of the ecological integrity of the Peace-Athabasca Delta in 2002:

1. Climate at Fort Chipewyan,
2. Water quality at sites on the Peace and Athabasca rivers and in Mamawi Lake,
3. Water levels in Lake Claire,
4. Clam shrimp abundance in Mamawi Lake,
5. Fish community composition and structure in Mamawi and Claire lakes,
6. Goldeye abundance in Mamawi and Claire lakes, and
7. Walleye and goldeye commercial catch in western Lake Athabasca.

The seven environmental indicators were chosen for the following reasons:

- Availability of historical information on fish communities and water quality,

- Availability of continuous and long-term annual collection of data for other purposes (climate, water levels, walleye and goldeye commercial catch),
- Relevance to the public (water levels, climate, walleye, and goldeye),
- Linkages within the Delta food web,
- Low cost to determine their status (clam shrimp, goldeye abundance), and
- One of the indicators (clam shrimp) is a rare species in Canada.

More than one indicator is necessary to assess the effects of potential stressors to an ecosystem. Several indicators are more likely to be sensitive to ecosystem impairment than a single indicator, which may only be responding to natural processes. But the integrity of the Delta ecosystem could be altered if any one of the seven indicators changed. The significant stressors to the Peace-Athabasca Delta in the future are likely to be: contaminants from municipal and industrial effluents within the Peace and Athabasca river basins, persistent contaminants originating from atmospheric deposition, overexploitation of natural renewable resources, and climate change. Ecosystem science may not be sufficiently advanced to be able to predict how aquatic life might respond to human-caused disturbances and contaminants. Therefore, the management of the Delta should be dynamic and flexible, and not tied only to the indicators proposed here.

Ecosystem Goal 1 - Climate: The climate of Fort Chipewyan and surrounding area follows historical annual and longer-term climatic patterns and their variability.

Commercial Fishing on Lake Athabasca (AENV)

> **Status:** The goal for climate is not being met. Mean annual temperature has increased and recent precipitation patterns and annual total precipitation differ from those of previous decades. During the period 1917 to 2000, there has been a significant increase in mean annual air temperature.

Ecosystem Goal 2 - Water Quality: Water quality is maintained to support native aquatic flora and fauna and for human drinking water.

> **Status:** From 1996 to 2001, the goal for water quality was not always met, because levels of dissolved sulphate and total dissolved solids in the Athabasca River occasionally exceeded Parks Canada objectives.

Ecosystem Goal 3 - Water Level: Water levels are maintained in the Peace-Athabasca Delta to provide habitat for aquatic life and to support boat and barge transportation in the region.

> **Status:** Water levels in Lake Claire remain within the historic range recorded since the construction of the Bennett Dam.

Ecosystem Goal 4 - Benthic Invertebrate Community: The abundance and diversity of aquatic benthic invertebrates is maintained in the Peace-Athabasca Delta. Benthic invertebrates are important foods of fish, and through the food chain, invertebrates can be an important source of contaminants in fish.

> **Status:** The benthic invertebrate indicator species, clam shrimp, were not present in Lake Mamawi in 2000 and 2002. The exact reason for the absence of this species is unknown, but it may be related to their life cycle requirements.

Ecosystem Goal 5 - Fish Community Structure: The fish community of the Peace-Athabasca Delta, which has both social and economic importance, is maintained. Residents of the Peace-Athabasca Delta participate in a productive regional commercial, domestic, and sport fishery. Walleye, lake whitefish, pike, and goldeye are the preferred species in these fisheries.

> **Status:** The goal for the fish community of Mamawi and Claire lakes is being met. The long-term relative abundance of fish species in the catch from Mamawi and Claire lakes has been remarkably stable and constant.

Ecosystem Goal 6 - Goldeye Abundance: The goldeye population of the Peace-Athabasca Delta is maintained at historic levels of abundance. Goldeye are an important part of the catch of the regional domestic fishery and the commercial fishery in western Lake Athabasca.

> **Status:** The goal for goldeye abundance is being met. The catch-per-unit-effort (CPUE) for goldeye in 1999 and 2002 was similar to the CPUE in 1973 and greater than the CPUE in 1987, 1992, and 1994.

Ecosystem Goal 7 - Walleye and Goldeye Fishery: Walleye and goldeye populations in the Peace-Athabasca Delta are maintained. Walleye and goldeye are the most important fish species in the commercial fishery and are an important part of the domestic and sport fish catch. Walleye and goldeye are an economic and nutritional resource to the residents of the Fort Chipewyan area. Table 7 shows commercial fish harvest from Lake Athabasca for 1992-2000. Populations in Lake Athabasca reflect the health of the ecosystem, because these fish use the delta for spawning and rearing.

> **Status:** The catch limits identified for this goal are being met.

Ecosystem Maintenance Indicators for the Slave River Delta, Northwest Territories, Canada

D. Milburn, D.D. MacDonald, T.D. Prowse and J.M. Culp

Ecosystem indicators were proposed for the Slave River Delta. The hydrology in the delta is critical to maintaining its ecological integrity. Therefore, the indicators proposed for the Slave River Delta are biological parts of the aquatic ecosystem that could be affected by changes in river hydrology. Of the hydrological factors that could affect the health and productivity of northern river ecosystems, the following are the most important:

- Timing, magnitude and duration of maximum and minimum flows.
- Timing and magnitude of autumn freeze-up and open-water period.
- Duration of ice-cover and open-water period.

Four biological ecosystem indicators were proposed. These provide a broad coverage of critical habitats during a variety of flows. The indicators are:

> Plant Community Index: The plant community along watercourses and in the water depends on river flows, ice breakup and flooding. If certain plants disappear or others come in, it likely indicates trends in flooding or drying out of aquatic habitats. This indicator is easy to measure and is supported by traditional knowledge.
>
> Goldeye: Goldeye was evaluated as being the key fish indicator, because it is most responsive to streamflow, especially conditions that affect turbidity. Measurements for this indicator include abundance, age structure and condition of fish.
>
> Shorebirds: Several species of shore and riparian birds are good indicators of wetland status. They are restricted to the delta area, and are responsive to break-up and peak flow conditions. The measurement for this indicator is reproductive success.
>
> Muskrat: Muskrat are good ecosystem indicators because they are aquatic and are responsive to a variety of hydrological conditions. Measurements for this indicator are reproductive success, population size and harvest statistics.

Additional research is needed to assemble specific information on these indicators and to test the proposed measurements for each indicator.

Table 7. *Annual commercial fisheries harvest (kg) from the Alberta portion of Lake Athabasca.*

Year	Goldeye	Northern Pike	Walleye
1992		34036	79180
1993	6000	38040	61727
1994		38973	44171
1995	10242		73235
1996	2391		54644
1997	1900	40000	79950
1998	8275	2538	77072
1999	9520		34393
2000	3356		34666

Delta Birds

An Investigation of Migrant Shorebird Use of the Peace-Athabasca Delta, 1999

G. Beyersbergen

This study focussed on the role of wetlands in the Peace-Athabasca Delta in providing resting/staging habitat for arctic nesting shorebirds. Survey efforts centred on the peak spring and fall migration periods when birds tended to concentrate. Its purpose was to identify the level of importance and the role delta wetlands played for migrant shorebirds. Additionally, we noted hydrological and habitat change on the delta wetlands to monitor effects on shorebird use of the area.

Shorebird use was surveyed by Cessna 185 floatplane in 1999. The aerial survey routes covered 1250 km of shoreline and included all available and recognizable shorebird habitat on the delta. They were flown in the same sequence for each of the four scheduled, two-day surveys. Additionally, several trips were made by airboat or helicopter to specific delta wetlands where concentrations of shorebirds were observed during aerial surveys. This assisted in identification of a number of shorebird species that proved difficult during aerial surveys.

Suitable shorebird habitat was characterized by exposed mudflats or shallow water with sparse or no emergent vegetation. It was widely distributed across the delta during the spring. In fall, however, germinating seeds quickly colonized mudflats exposed in the early spring and carpets of vegetation covered areas that were once bare soil. The greatest changes came about because of the summer flood of the Athabasca River. All delta lakes and basins in this open drainage system were flooded. Water levels remained high into early August, and the effects of habitat loss were seen in the concentration of shorebirds on the remaining shorebird wetland habitat.

Shorebirds were observed on nearly all lakes and perched basins with suitable habitat in the delta during one season or the other (*Table 8*). The shorebird distribution changed between the spring and fall surveys as habitat conditions changed. Key wetland areas and lakes with high shorebird numbers in spring and fall included Welstead, Frog and Hilda (East and West) lakes, and the lake basins of the Birch River delta. These basins are part of a restricted drainage system and were not affected by the Athabasca River summer flood. The perched basins of the Sweetgrass, Prairie River, Deep Point Complex, Lynx Stand Bay and Mamawi (East) had considerable shorebird use.

Eighteen species of shorebirds used the delta during the 1999 field study. Shorebirds seen included eight species of arctic migrants and local breeding species.

The breeding range of 10 species overlaps the delta – birds within this group were usually observed as individuals, pairs or in small groups. Spring observations of these species were widely scattered throughout the delta wetlands, which indicates breeding activity. A medium-sized shorebird that breeds locally, but was not identified, was called "yellowlegs." It showed increased numbers during fall aerial surveys. During ground visits they made up over half of the birds identified on Welstead Lake and basins of the Birch River delta. This may indicate that some delta wetlands provide important habitat for pre-migration staging of local breeding species in the fall.

The Peace Athabasca Delta wetlands provide habitat for shorebirds for nesting and staging, including local breeders and arctic migrants. Although the level of use is not as high as that encountered on some Canadian prairie wetlands, shorebird use does occur. Maintenance of the ecological integrity of the delta ecosystem would ensure that shorebirds could use the area in the future. The dynamic nature of the delta ecosystem and external factors along the continental migration corridor will influence annual migrant shorebird use of the area. In the long term, shorebirds, being opportunistic in nature, will probably use the delta wetlands when the need arises and habitat conditions are suitable.

Delta Shorebirds (G. Beyersbergen, CWS, Environment Canada)

Table 8. *Shorebird observations, shown as percent of survey total, for each of the sites in the Peace-Athabasca Delta.*

Site Name	May 24 / 25	May 30 / 31	July 24 / 25	August 10 / 11
Lake Claire - East - Sheltered Bays	3.91	9.05	5.57	1.22
Lake Claire - Shoreline: NW to SE	3.67	1.39	0.80	1.39
Birch River Delta Lakes	16.86	13.42	34.95	48.44
Welstead Lake	9.79	12.43	16.40	11.78
Frog Lake	1.61	14.03	6.16	7.09
Hilda Lakes (East / West)	7.95	2.79	10.62	6.39
Otter Lake	3.18	8.85	2.63	0.09
Mamawi Lake	9.62	6.11	0.25	1.14
Limon Lake	0.03	0.00	0.00	1.19
Richardson Lake	1.94	0.71	0.02	0.73
Galoot Lake	0.71	19.67	0.00	0.05
Athabasca River Delta (Lake Athabasca shore)	3.45	0.56	0.00	0.60
Perched Basins:	[37.29]*	[10.99]	[22.59]	[19.9]
Sweetgrass Area	15.29	3.38	2.16	4.24
Mamawi - East	4.47	2.52	4.50	0.39
Prairie River	8.69	2.84	6.06	2.16
Deep Point Complex	3.12	1.37	6.02	8.58
Lynx Stand Bay	5.72	0.88	3.85	4.53
Total:	100% (7,568)	100% (17,918)	100% (22,818)	100% (13,440)

* = Total for all perched basins in the area.
(###) = Total number of birds observed during the survey.

Aerial Survey Over the Delta (Ducks Unlimited)

Large Habitat Complexes (Ducks Unlimited)

Peace-Athabasca Delta Waterbird Inventory Program: 1998-2001 Final Report

E. Butterworth, A. Leach, M. Gendron, B. Pollard and G. Stewart

In 1996 and 1997, the Peace-Athabasca delta received floodwaters after 22 years of drying. The lack of waterfowl surveys during this re-wetting interval was unfortunate, because it was an opportunity to investigate how the water bird use of the delta responded to flooding. Recession rates of the delta's perched basins to a dry condition are on the order of 5-7 years. Resource managers hypothesized these basins would be optimally attractive to waterfowl for about three years in the absence of a subsequent flood event. Increasing our understanding of how the delta responds to extended dry periods is critically important to future ecosystem management of the delta. Of equal interest and importance is how waterfowl respond to the re-watering of the delta. It was predicted that waterbird use would increase at first, and then decrease during subsequent years as the basins dried.

Our surveys on the delta, which started in 1998, documented breeding, moulting and staging waterfowl populations at a very high level. Staging waterfowl populations showed a dramatic decline from 1999 to 2001, while breeding waterfowl populations did not decline until 2001. Brood production declined from 1998 through 2000 but increased in 2001, although the increase was less than that recorded for 1999. We do not know why the different components of the life cycle of waterfowl on the delta showed different population changes over the three years.

United States Fish and Wildlife Service survey data of waterfowl breeding pairs in the area indicated an average increase of 43% after the flood compared with the average for five years before the flood, and an increase of 89% in total numbers of ducks for 1998 and 1999. Populations returned to pre-flood levels in 2000. No increase in waterfowl was noted in 1997, the year of the flood.

The response of waterfowl to the flood of 1996/1997 and the subsequent decline in water levels supports the hypothesis that flood events are crucial to waterfowl use of the delta. The delta continues to host substantial numbers of moulting and staging waterbirds from all four North American migratory flyways. The delta is a world-class wetland – very few habitats in North America compare in its importance for waterfowl.

Aerial Surveys (Ducks Unlimited)

Contaminants

A contaminant is any chemical or material that enters a system (the environment, human body, food, etc.) where it is not normally found. Some contaminants are highly toxic, such as dioxins and furans. Some may increase through the food chain or bioaccumulate. This is the process whereby certain chemicals accumulate in animal or plant tissues to levels that are much greater than levels in the environment. The degree of contaminant bioaccumulation is a key factor in the establishment of water and sediment quality guidelines (*see the appendix for further information on contaminants*).

The *Northern Rivers Ecosystem Initiative* focussed considerable attention on contaminants in the northern river basins. Many of the studies were designed to assess contaminants in specific sources, such as effluents, and in the environment. Some of these assessed trends over time and along the rivers. Others looked at the impact of these chemicals on the health of fish. These studies are summarized below.

Contaminant Sources

The main contaminant sources investigated during NREI were pulp mill effluents, atmospheric transport of mercury and oil sands operations.

Pulp Mills

Pulp mill effluents are a source of contaminants to the rivers on which they are located. Figure 15 shows the daily quantities (or "loads") of three contaminants in effluents from the seven pulp mills in northern Alberta. The three contaminants shown in the graph are Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), and Adsorbable Organic Halides (AOX). BOD is an indicator of the amount of organic matter in the water, which uses up oxygen as it decomposes. TSS is the amount of particles suspended in the water – soils, organic and inorganic matter and microscopic organisms. AOX is another name for chlorinated organic compounds (*see below*). Also shown is the total pulp production for these mills. The total tonnage of pulp produced has more than doubled in this period. The loads of all of these groups of substances have generally declined over this 13-year period, and AOX has declined by the largest proportion (although the AOX discharged by the two kraft mills on the Athabasca River has increased slightly). The loads of total suspended solids and BOD have also increased, likely because pulp production has also increased.

One of the compound groups measured by the AOX tests is dioxins and furans. Levels of dioxins and furans in bleached Kraft pulp mill effluent have declined since the early 1990s.

Dioxins and furans could not be detected in effluents from ALPAC from 1997-2002, from Daishowa from 1997-2001, from Weldwood in 1998-2002 and from Weyerhaeuser in 1998-1999. The three thermo-mechanical pulp mills in Alberta do not produce dioxins or furans in their pulping process.

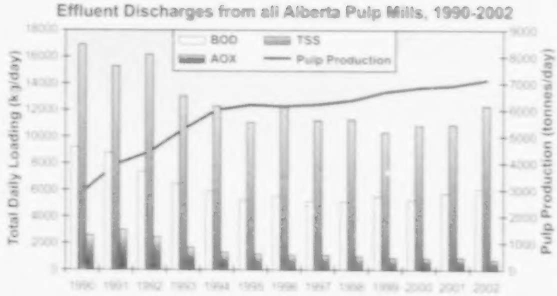


Figure 15. *Daily loads of biochemical oxygen demand (BOD), total suspended solids (TSS) and adsorbable organic halides (AOX) from 1990 to 2002. Also shown is daily pulp production for this period. (AENV)*

AOX (Adsorbable Organic Halides)

The AOX test measures organic compounds that have halides attached and stick to an activated carbon filter. Halides are highly reactive elements in the halogen family: fluorine, chlorine, bromine, and iodine.

These elements bond easily with organic substances, allowing quick entry into the environment and the food chain. Because chlorine is by far the most common halide present in pulp mill effluent, the AOX test essentially measures chlorinated organic compounds.

Characterizations of EDCs at Pulp Mill Sites in the Northern Rivers Basin

L.M. Hewitt, M.E. McMaster, M. Kohli,
A. Pryce, J.L. Parrott, G.R. Tetreault
and G.J. Van Der Kraak

It is well known that reproduction in fish can be impaired when they are exposed to pulp and paper mill effluents. But the compounds responsible for problems in fish reproduction seen at many sites have not been identified. Final effluents are highly complex. They consist of hundreds of compounds, many of which are unknown. Wood-derived compounds present in effluents include wood extractives and lignin. Effluent composition is affected by mill-to-mill differences in process technology, process operation, differences in the types of wood and chemical interactions among the different waste streams.

The objective for our work in the northern river basins was to conduct detailed studies at modern mills that have used secondary treatment since startup. We sought to characterize bioavailable substances while assessing overall fish performance and endocrine related endpoints.

Specific objectives were:

- To look at effluents from the northern river basin mills for potential endocrine disruption activity, and to examine the influence of mill process type and treatment technology on such activity.
- To identify effluent constituents functioning as endocrine disruptors using bioassay-directed chemical fractionation techniques with wild fish tissues and specific wood furnish.

Our studies focussed on *ligands* for sex steroids in effluent – those bioavailable to fish – and an assessment of their content in wood furnish. The mills in this study within the northern basins were Millar Western and Alberta Newsprint located in Whitecourt and Weyerhaeuser located in Grande Prairie. These are "modern" mills – they are all relatively new, have had secondary treatment for the life of the mill and meet the new federal pulp and paper effluent regulations initiated in 1992.

Samples were collected from the mill effluents and prepared for bioassay testing. The extracts from this preparation were tested for their ability to bind to fish sex steroid hormone receptors using male goldfish hormone receptors and sex steroid binding protein assays. Compounds that bind to each of the receptors tested were detected, but there were no correlations of activity with the type of mill process used or the type of effluent treatment. Both increases and decreases in hormonal activity were observed after secondary treatment of the effluents, so it is unclear what effects, if any, conventional effluent treatment is having on levels of hormone active compounds in the effluents.

Endocrine Disruption

Some substances in pulp mill effluent are capable of interfering with reproduction in fish. These substances, called ligands, mimic natural male and female fish hormones. They can bind to proteins called receptors in the fish gonads. As a result, the fish can't reproduce normally.

These substances can be tested by doing a "bioassay" – that is, by extracting them from pulp mill effluent. Then the scientists put them with goldfish male hormone receptors to find out whether they mimic the hormone or not.

The next objective of our studies was to begin to identify effluent constituents that could function as endocrine disruptors. We attempted to use effluent from the pulp mill at Grande Prairie in a controlled exposure experiment, because wild fish collections indicated the highest potential for endocrine disruption at this site. Unfortunately, the study could not be completed due to unforeseen mortality during the wild fish tests. However, there was evidence of male hormone mimic compounds in the Wapiti River, similar to that from other mills studied in Canada.

In another part of the study, wood chips from the Grande Prairie mill were used to investigate whether compounds associated with reproductive effects can be obtained directly from wood feedstock. The wood samples contained about half white spruce, half lodgepole pine and a small percentage of balsam fir. The chips were soaked in chemicals to extract the compounds responsible for fish reproductive problems.

Wood chip extracts had hormone mimics in all of the assays although the potency varied. Preliminary identification of the major components in these extracts suggested that organic chemicals called *stilbene* make up a large proportion of the samples.

Collectively, these observations provide plausible linkages between the release of bioactive substances from pulp mills in the northern river basins and alterations in reproductive function in wild fish collected from the receiving environments.

Pulp Mill Effluent to Wapiti River (AENV)

Atmospheric Deposition of Toxins

Many First Nations people in the northern basins eat traditional foods. As a result, people worry about the health impact of environmental toxins in aquatic ecosystems.

For example, mercury is known to affect learning ability and brain development in children. It can be carried long distances by air currents, and it may bioaccumulate in the food chain. Atmospheric mercury originates from both natural and human sources. Once in the atmosphere, mercury may travel long distances before being deposited on the land or in water. Elemental mercury is the main form of mercury in the atmosphere. This form has an atmospheric lifetime of about one year before being deposited to the Earth's surface. Other forms of mercury stay in the atmosphere for much shorter times, and hence are deposited close to where they are emitted.

Once it is deposited on the land, runoff during rain or snowmelt can transport it into rivers or lakes (*Figure 16*). Then, plants and animals can take it up.

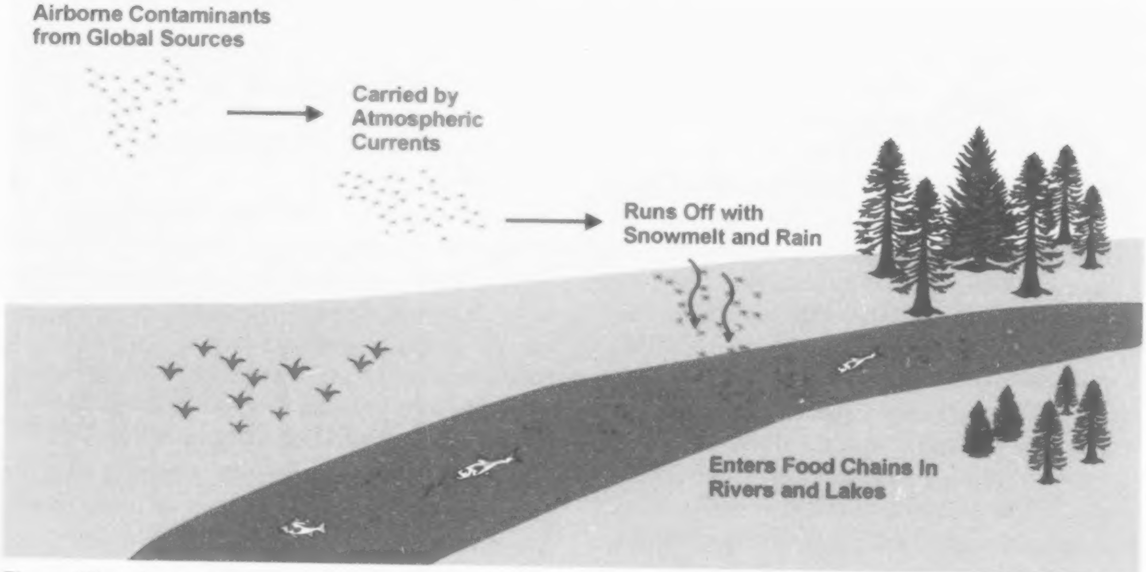

Airborne Contaminants from Global Sources
Carried by Atmospheric Currents
Runs Off with Snowmelt and Rain
Enters Food Chains In Rivers and Lakes

Figure 16. *Atmospheric deposition. Contaminants fall to earth with rain or snow, and are transported by runoff to creeks, rivers and lakes. Source: (AENV)*

Atmospheric Contribution to Mercury Loading in the Northern Aquatic Systems

B.J. Wiens, M. Kellerhals and A.D. Pankratz

Mercury contamination in fish in the Athabasca River has not changed very much since the late 1980s. The highest concentrations tend to be at the lower end of the river. Some of this mercury originates from the water and the sediments, but some of it may also come from atmospheric deposition onto the watershed.

The purpose of the following NREI study was to begin to address the atmospheric contribution of mercury to aquatic systems. The bulk of mercury emissions in Alberta come from the burning of coal for power generation. Most of this power generation takes place in Central Alberta near Edmonton, which is 600 km south-southwest of the study area. The oil sands plants around Fort McMurray (300 km south of the measuring site) also emit some mercury.

To measure atmospheric deposition of mercury, an instrument was located at the Fort Chipewyan airport at the Environment Canada weather station. The average atmospheric concentration of total gaseous mercury (TGM) for the whole period of record was 1.37 nanograms/cubic metre (ng/m^3). The highest hourly value recorded was 2.18 and the lowest was 0.55 ng/m^3. In comparison, the average concentration at Canadian Atmospheric Mercury Network sites was 1.60 ng/m^3. The greatest daily variability in levels occurred during the month of August, and ranged about 23% above and below the average daily value. No significant daily variability occurred during January.

The pattern of daily variability observed at Fort Chipewyan is similar to that observed at other sites in Canada. Figure 17 shows the monthly average atmospheric mercury concentration observed from June 2000 to July 2001 (transposed to match the available monthly data from other Canadian sites) at Fort Chipewyan. Also on this graph is the average for sites across Canada and at Alert in the high Arctic. A comparison with other stations across Canada shows that mercury at Fort Chipewyan is below the national average for all months.

The annual cycle, with a winter maximum, is similar to that at other Northern Hemisphere sites. It is likely that high levels in winter are caused by increased fossil fuel emissions, which contain mercury. Other studies have shown that mercury deposition tends to be lower in the western Arctic compared with that in the eastern Arctic. The lower concentrations observed here (western subarctic) relative to Alert (high eastern Arctic) support that result.

The highest observed mercury value at Fort Chipewyan was 2.18 ng/m^3 at 3:00 pm on the 17th November 2000. On this day, airflow was from the west to northwest, but turned south between noon and 6 pm. Other air pollutants such as sulfur dioxide and nitrogen dioxide were also elevated. Since oil sands operations in the Fort McMurray area are the only nearby source of significant sulfur dioxide emissions it is also likely that those emissions caused the high mercury concentrations.

The data from this study indicate that nearby industrial sources (Fort McMurray) and more distant ones (Edmonton area) are having only a small effect on atmospheric mercury concentrations in the Peace-Athabasca Delta.

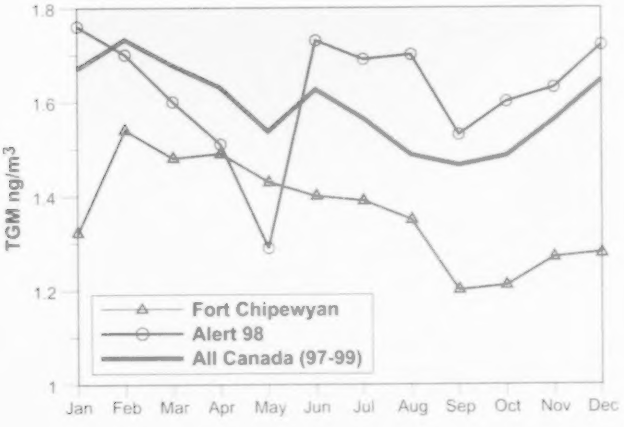


Figure 17. *Monthly average atmospheric mercury (TGM) at Fort Chipewyan compared with average levels at other Canadian sites and to Alert, Nunavut.*

Oil Sands

Many studies have focussed on the nature of effluent produced by the oil sands industry and its impact on the environment. The contaminants of concern are mostly hydrocarbons – those produced either naturally or during mining of the oil sands. The spatial distribution of these hydrocarbon contaminants has also been investigated. Usually, this is done by determining the amount of hydrocarbon associated with sediments deposited on the bottom of a river.

Natural hydrocarbon outcrops are present throughout the oil sands area. These outcrops may be responsible for some of the biological responses seen in areas not exposed to industrial effluent. The oil sands represent a natural source of hydrocarbons to the environment. It is difficult to determine the true industrial impact in rivers unless the impact from natural hydrocarbons can be measured and differentiated from those of man-made origin.

The Panel on Energy Research and Development (PERD) (*see more information p. 47*) conducted several studies to assess the impact of oil sands on the Athabasca River.

Assessment of Natural and Anthropogenic Impacts of Oil Sands Contaminants within the Northern River Basins

R.B. Brua, K. Cash and J.M. Culp, Editors

The main objective of this project was to improve our understanding of the spatial distribution, nature and extent of natural hydrocarbon releases to the environment within the oil sands region. We focussed on assessing the physical characteristics of the lower Athabasca River basin to be able to determine the origin of the oil sands sediments. This assessment was based on a review of historic sediment data for the lower Athabasca River, along with an evaluation of channel stability from aerial photography and on-site investigations. In addition to assessing the changes in topography by river processes along the lower Athabasca River, considerable effort was also focussed on many of the tributaries that also come in contact with the oil sand-bearing strata. Water, suspended sediment and bed material were also sampled and analyzed for polycyclic aromatic hydrocarbons (PAHs).

The sediment budget of the Athabasca River was calculated. The mean annual suspended sediment load at Fort McMurray is 5.2 million tonnes and further downstream at Embarras the sediment load is 6.4 million tonnes. Over half of this difference originated from the tributaries, mainly from the Clearwater River. Accounting for the various inputs, the net balance, about 0.55 million tonnes, can be assumed to originate from bank erosion between the two stations on the main stem of the Athabasca River. Aerial photographs showed that there were three main sites that were eroding heavily along the lower Athabasca River. Site investigations confirmed that these sites were eroding, and there seemed to be oil sands material in the cutbank. As well, "tar balls" were found as far as 100 km downstream from the last known outcrop of tar sands. They were likely deposited during flooding more than 9000 years ago. The oil sands deposits are now being re-exposed and potentially becoming re-mobilized into the Athabasca River.

Naturally occurring oil sand sediments are more prevalent in tributaries that are incised into the oil sands. We determined that less than 3% of the total annual sediment load of the Athabasca River at its outlet is made up of oil sands material. Because of this we would expect to find only minimal amounts of naturally derived PAHs in the lower reaches of the Athabasca River System. But it is possible that episodic flood events could transport and deposit larger volumes of oil sands sediment along the river or perhaps into the Peace Athabasca Delta or Lake Athabasca.

Chemical analysis of the sediment and water samples showed that only trace amounts of PAHs were present in water, but higher amounts were in sediments. Analyses of sediments confirmed that the tributaries passing through the Fort McMurray oil sands regions contain significant levels of naturally derived hydrocarbons. It was determined that these PAHs are derived mostly from natural sources, likely natural oil-seeps in the regions. Once the tributaries drain into the Athabasca River they become diluted and concentrations fall to values typical of remote pristine areas where there is little or no exposure to oil sand hydrocarbons.

Summary. The individual parts within the PERD Study cover a variety of issues but taken together indicate that major tributaries of the lower Athabasca River contain significant levels of naturally derived hydrocarbons. Much of the PAHs seen in Athabasca River sediments came from upstream natural sources. According to the coring studies, amounts of PAHs have not increased over time.

We can draw the following conclusions from the PERD Study:

- Naturally occurring hydrocarbons are present in the lower sections of the Athabasca River.
- There is a slight to moderate impact of these materials on local plants and animals.
- There is no evidence of impacts from oil sands operations on hydrocarbon distribution or sediment toxicity.

The PERD study played an important role in the design and implementation of local monitoring programs (e.g., the *Regional Aquatic Monitoring Program*, RAMP). The results of this work will continue to influence the priorities of aquatic monitoring programs within the region.

Contaminants in the Environment

Within aquatic systems, environmental contaminants may be present in water, plants or animals. But the greatest mass of many contaminants is in sediments – particles of soil, sand and organic materials. These might be suspended in the water, giving it a cloudy or murky look. Or, they may be deposited on the bottom of a water body and contribute to the bottom "mud". In rivers, sediments are usually deposited on the bottom when river flows decrease. When flows increase, the sediment can be picked up and transported downstream. Sediment is ecologically important, because it contains nutrients that can rejuvenate habitats. But contaminants such as heavy metals and organic pollutants can attach to sediment particles. Fine-grained particles tend to have the highest amounts of these contaminants. These sediments may become a major source of contaminants to plants and animals in the aquatic system through food chains. Some of the contaminants of concern in the northern rivers are polychlorinated biphenyls (PCBs), dioxins and furans, AOX, mercury and hydrocarbons (*see the appendix for more information on these*).

Contaminants in the Peace and Athabasca River basins were studied during the *Northern River Basins Study*. NREI papers include contaminants in water, suspended sediment and bottom sediment.

Wapiti-Smoky Rivers Confluence (AENV)

Water

Adsorbable Organic Halides in Athabasca River Water

L. Noton

The group of contaminants known as Adsorbable Organic Halides (AOX) has been monitored at several sites in the Athabasca River. AOX is composed principally of chlorinated organic compounds. Although some AOX occurs naturally, these compounds can be high in treated effluent from bleached kraft pulp mills and to a lesser extent municipal sewage. AOX concentrations are measured in the winter because flows are low, which results in less dilution of effluents. Therefore, concentrations of contaminants should be highest at that time. We found the lowest concentrations of AOX upstream of Hinton and the highest concentrations at the Windfall Bridge below Hinton. AOX concentrations declined during the early to mid-1990s, but have increased slightly in recent years (*Figure 18*). The pulp mill in Hinton is the main source of AOX in the area, which is why concentrations at the Windfall Bridge are higher than those upstream.

The decline in AOX concentration in the river water over time reflects technological and effluent treatment improvements at pulp mill facilities (*Figure 18*). The mill in Hinton switched its bleaching agent from elemental chlorine to chlorine dioxide in 1993. As a result, the amounts of AOX entering the river from pulp mill effluents in the Athabasca River basin has decreased by about 60% since the early 1990s. Within the last few years, however, the amount of AOX released by the pulp mills on the Athabasca River has increased slightly, and concentrations in the river water have also increased.

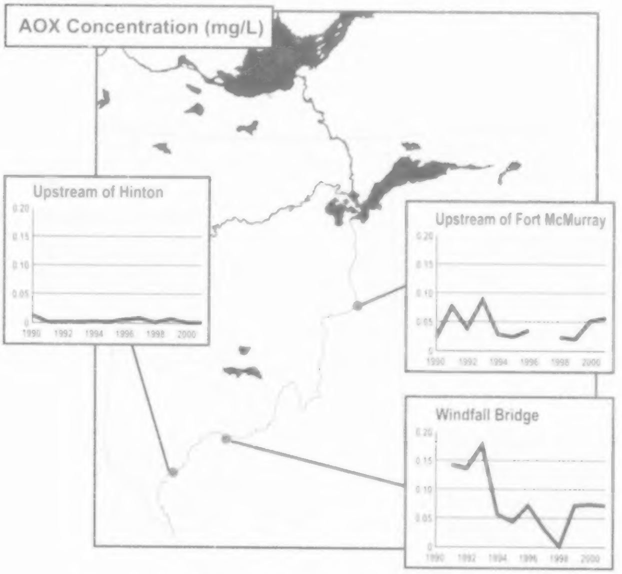


Figure 18. *Annual winter concentrations of adsorbable organic halides (AOX) in the Athabasca River.*

Some of the compounds included in AOX, such as chlorinated phenolics, have declined and are within the guidelines for protection of aquatic life. But the long-term effects of these chemicals on fish are not yet fully understood. Monitoring of adsorbable organic halides continues in the Athabasca Rivers and in pulp mill effluents.

Suspended Particles in Water

Contaminants in Water, and Suspended Particles from Specific Reaches of the Peace-Athabasca System

M. Alaee, M. Lowen, R. Crosley, J. Buonomo, G. Lawson, D. Bennie, F. Yang, K. Burniston and D. Muir

During the *Northern River Basins Study*, dioxins and furans were detected in suspended sediments obtained by continuous flow centrifugation of large volumes of river water from the Athabasca River between Hinton and Whitecourt. Similar techniques were used in studies in the Wapiti River downstream of the pulp mill at Grande Prairie. But the large-volume technique was not used to assess levels of PCBs and other contaminants during NRBS.

During NREI, we used the large volume technique to survey river water for persistent organic chemicals, dissolved mercury, and dissolved endocrine-disrupting chemicals in water and suspended sediments. This work complemented other NREI work on contaminants. Suspended particles can be removed and then contaminants analyzed in both the sediments and the remaining water. If a limited number of bottom sediment samples are collected as well, they can be compared with contaminant levels in the suspended sediments and water.

Sampling for contaminants in northern Alberta rivers took place from 1998 to 2001. Sampling during 1998 to 2000 focussed on the Wapiti River near the city of Grand Prairie. In 2000 and 2001, sampling for water

Continuous Flow Centrifugation

This is a technique that uses a centrifuge to extract suspended sediment from river water. River water is pumped continuously through it, and the suspended sediments and chemicals bonded to them can be separated from the water. Then the water and sediment can be analyzed separately.

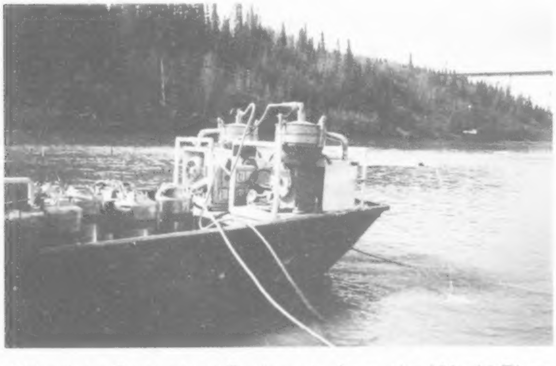
and sediments took place at four sites on the Athabasca River. Suspended sediment samples were collected continuously for up to 24 hours depending on the suspended sediment content in the water. Duplicate large volume water samples were collected at each site by pumping centrifuged water through XAD-2 resin in a Teflon tube in the field. Thirty-six large-volume water samples and 36 suspended sediment samples were collected from the following sampling locations on the Wapiti River:

- A control site where the Wapiti River crosses highway 40. This was labelled km 0.
- Below the sewage treatment plant effluent at km 6.0.
- Below the CNR Bridge at km 12.5.
- Below the confluence of the Bear River with the Wapiti River at km 25.

Sampling locations along the Athabasca River included:

- A control site 7 km above Hinton at km 0.
- At Obed at km 19.
- Near Windfall at km 176
- Blueridge at km 234.

Samples were analyzed for PCBs. dioxins. furans. mercury and other contaminants.



Collecting Suspended Sediments from the Wapiti River Below the Sewage Plant Discharge *(Environment Canada)*

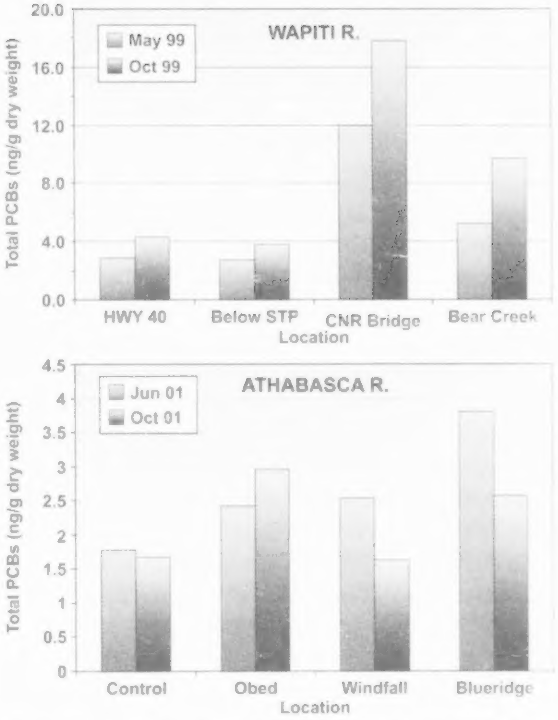


Figure 19. *Concentrations of PCBs in suspended solids from the Wapiti and Athabasca rivers.*

PCBs were present dissolved in water and bound to sediment particles in the Wapiti and Athabasca rivers. In water. concentrations ranged between 0.3 (below sewage treatment plant) and 1.1 nanogram/L (Bear River) on the Wapiti River and 0.3 (Blueridge) and 1.4 ng/L (Windfall) for the Athabasca River. These concentrations are similar to those in the Mackenzie River (3.0 ng/L) and in Amituk Lake in Nunavut (1.2-1.3 ng/L).

In the Wapiti River. PCB concentrations bound to suspended particles ranged between 2.9 ng/g above Grande Prairie (control site) and 17.8 ng/g (below the CNR bridge) (*Figure 19*). For the Athabasca River. highest concentrations were at Blue Ridge (3.8 ng/g) while lowest concentrations were at Windfall (1.6 ng/g).

Dioxins and furans were present in suspended sediment from the Athabasca and Wapiti rivers. On the Wapiti River system. concentrations of dioxins in suspended sediments ranged between 0.008 ng/g (control site) and 0.408 ng/g (Bear River). For furans. concentrations ranged between 0.001 ng/g (control site) and 0.033 ng/g (Below CNR Bridge). The type of dioxin present in the Wapiti River suggests that it came from pentachlorophenol, a pesticide usually used as a wood preservative. The main type of furans was similar to that produced during chlorine bleaching of pulp. The relatively high concentration below the CNR bridge likely can be attributed to the historical use of chlorine in the pulp mill located above the sampling site.

In the Athabasca River, concentrations of dioxins in suspended sediments ranged between 0.014 ng/g (control site) and 0.050 ng/g (Blue Ridge). For furans, levels ranged from 0.003 ng/g (control site) and 0.012 ng/g (Blue Ridge). The main type of dioxin in the Athabasca River was similar to that in the Wapiti River, but the concentration for this type was much lower. As in the Wapiti River, the type of furans suggests previous use of chlorine by pulp mills for bleaching. However, a different type in spring 2001 can be attributed to incineration and/or long-range air transport. These concentrations are significantly lower than the levels seen in the Athabasca River in 1992, likely because of process changes in the pulp mills.

Mercury levels in Athabasca and Wapiti Rivers ranged between 1.7 and 5.4 ng/L. These levels are similar to those observed in other pristine rivers such as the Slave River at Fort Smith, which ranged between 1.7 and 15 ng/L.

Bottom Sediments

Investigations of PCBs in Bottom Sediments of the Bear-Wapiti-Smoky-Peace and Upper Athabasca River Systems, 1989-2000

R. Hazewinkel and L. Noton

Alberta Environment has conducted detailed sampling and analysis of PCBs in bottom sediments from the Wapiti, Smoky, Peace, and Athabasca rivers, to look into the source and distribution of these contaminants, as recommended by the NRBS.

Wapiti River: In autumn 1997, Alberta Environment collected bottom sediments from the Wapiti and Smoky rivers to help explain the presence of PCBs in fish and to identify potential sources. Concentrations of PCBs in bottom sediments throughout the Wapiti River are very low – they fall below the CCME interim sediment quality guideline for PCBs by more than a hundred times. But concentrations are somewhat higher downstream of the Grande Prairie area. Concentrations in sediments were slightly higher in the Bear River, a tributary of the Wapiti River, which flows through Grande Prairie.

PCBs

Polychlorinated Biphenyls (PCBs) are synthetic compounds that can last for many years. They do not break down easily on their own, and are difficult to destroy.

They were used as ingredients in many industrial materials and to make coolants and lubricants for certain kinds of electrical equipment.

PCBs move up the food chain by getting into the body fat of animals and staying there for a long time.

In 1998, additional samples were collected from the Bear River. Levels of PCBs in sediments were significantly higher in the Bear River than levels in the Wapiti River, although they were still below CCME guidelines (*Figure 20*). At three sites in the Bear River upstream of Grande Prairie, PCBs were consistently low, although somewhat higher than at upstream sites in the Wapiti River. Within Grande Prairie, levels of PCBs were about five times higher in Bear River sediment than at the three upstream sites. Downstream of the city, PCBs appeared to decline in a downstream direction. By the time the river reached its confluence with the Wapiti River, levels were similar to those upstream of Grande Prairie.

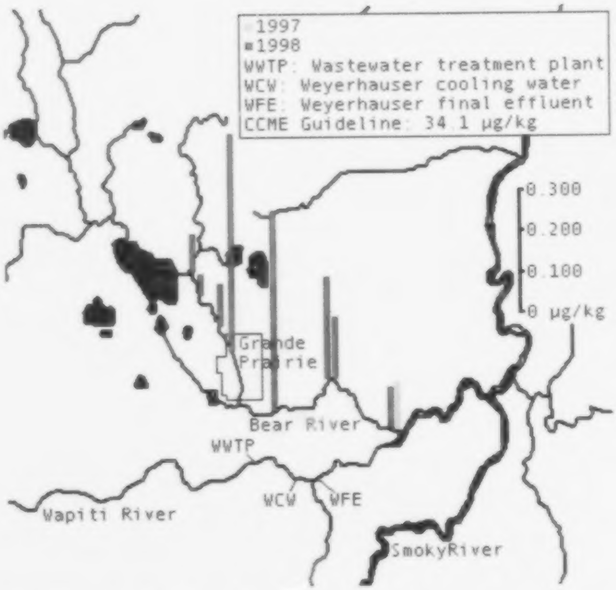

□ 1997
■ 1998
WWTP: Wastewater treatment plant
WCW: Weyerhauser cooling water
WFE: Weyerhauser final effluent
CCME Guideline: 34.1 µg/kg
0.300
0.200
0.100
0 µg/kg
Grande Prairie
Bear River
WWTP
WCW
WFE
Wapiti River
SmokyRiver

Figure 20. *Total PCB levels in sediment samples collected from the Bear River in 1997 and 1998.*

Staff of Alberta Environment and Environment Canada reviewed the location of storage sites and known incidences of PCB release that might contribute to the elevated PCBs in fish of the Wapiti-Smoky river system. An accidental release of approximately 1300 L of Askarel occurred at the Weyerhaeuser pulp mill in 1978. Askarel is a generic name for a class of synthetic liquids containing a proprietary mixture of PCB (40-60%) and trichlorobenzene that was used as an electrical insulating fluid. It reached the Wapiti River primarily through the process effluent treatment system. Contaminated sediments contained within the treatment system were removed to the mill's secured chemical landfill site.

The PCB spill at the pulp mill is the only known significant release of PCBs into the Wapiti River. Upstream of the facility, sediment PCB concentrations are low and are similar to baseline levels for other Alberta rivers. Sediment PCB concentrations below the final effluent discharge are variable and frequently higher than background levels. There is also evidence of some PCB contamination in sediments collected below the former storm sewer outflow, but above the final effluent outflow. The 1978 spill may be a factor in the higher levels of PCBs seen in 1997, but concentrations were so low that it is difficult to determine the full cause.

During a review of contaminated sites and spills in the basin, we found that PCBs were used at CFB Beaverlodge, a decommissioned Department of National Defense facility. After the decommissioning of the base, an extensive effort was made to remove residual contamination. It is unlikely that this site is a source of PCB contamination to either the Bear or Wapiti Rivers. Other sites in the Bear River basin have been identified as potential locations of historic PCB use or storage, but it is not known whether spills or contamination occurred at any of these sites.

A statistical procedure was used on the PCB data from the Wapiti and Bear rivers to try to identify sources. The sediment data appear to sort into three main groups: 1) sites located upstream of the pulp mill on the Wapiti River, 2) Wapiti River sites between the pulp mill and the confluence with the Bear River, and 3) sites along the Bear River. This analysis suggests that the elevated PCBs in the Bear River are of a different type than those in the Wapiti River. Although no specific spill or contaminated site has come to light as the possible source for the Bear River, there may be small older sources within Grande Prairie or the Bear River basin. These have not been identified so far. Before the restrictions on the use of PCBs that came into effect in the early 1970s, PCB storage and disposal was subject to a less stringent level of scrutiny.

Athabasca River: Sediment samples were collected from the Athabasca River in 2000. PCB concentrations upstream of Hinton were consistently higher than background levels in the Wapiti-Smoky River basin. The Athabasca River at this point is fed mainly by glacial runoff and snowmelt, and therefore the atmosphere may be a more important source for PCBs than in the Wapiti-Smoky system. As well, there is more human activity in the upper Athabasca River basin, and therefore the potential for contamination is greater. Nonetheless, all the PCB concentrations measured in sediments of the upper Athabasca River system were much lower than the CCME guideline for PCBs in sediments.

Sediment PCB concentrations in Hardisty Creek, a tributary of the Athabasca, were about 10 times higher than background levels for the Athabasca basin. Although these PCB levels are well below the CCME guideline, Hardisty Creek may constitute a source of contamination for the Athabasca River. Sediment PCBs in the Athabasca River about 4 km downstream of Hardisty Creek were significantly above background concentrations. PCB concentrations at sites further downstream suggest that contamination extends more than 4 km, although at reduced levels.

The source of the elevated PCBs in Hardisty Creek is not known. This creek flows through Hinton and could potentially receive contamination from a number of human activities in the area. In addition, other sources along the Athabasca River in that vicinity could also contribute to the slightly elevated PCB levels observed downstream of Hinton. Alberta Environment, in co-operation with Environment Canada, will review known PCB incidents and storage sites in the Hinton and general upper Athabasca River basin area, to assess whether there may be any linkage to PCBs in river sediment and aquatic organisms.

Observations on Sediment Chemistry of the Slave River Delta, Northwest Territories, Canada

D. Milburn, M. Stone, M. English and T. Prowse

Studies were conducted in the Slave River Delta to assess levels of heavy metals in bottom sediments. We collected a total of 31 sediment samples from 26 sites across the delta, and found that levels of chromium, mercury, arsenic and cadmium exceeded CCME guidelines for sediment quality.

Levels were highest in central areas of the delta. These areas are transitional between the outer, water-dominated marsh and the apex of the delta, which is relatively dry. It is likely that levels of these metals were higher in this area because vegetation trapped fine-grained sediments. Finer-grained sediments tend to have higher concentrations of metals than more coarse sediments. It is likely that aquatic plants play a role in the uptake and redistribution of metals in the delta.

Sediment Bound Contaminants in a Remote Northern Delta

D. Milburn and T. Prowse

We looked at industrial contaminants in sediments of the Slave River Delta. Many of these chemicals last a long time in the environment. As well, aquatic organisms in the north are long-lived, and so may accumulate contaminants to a greater degree than those in southern areas.

Bottom sediment samples were collected from two channels of the Slave River Delta in which fine-grained sediments are deposited.

They were analyzed for chlorophenolics, PAHs, dioxins and furans and PCBs – all potentially from industrial sources.

We found that concentrations of contaminants were highest just before ice breakup in winter, when flows were low. Concentrations of dioxins and furans, PCBs and chlorophenolics in the Slave River Delta were higher than in samples collected at Fort Smith and offshore in Great Slave Lake. Levels of Dioxins and furans and PCBs exceeded CCME *Interim Sediment Quality Guidelines*, but sources are unknown. Low flow, ice-covered conditions favour the deposition of fine-grained sediments and associated contaminants.

Effects of Contaminants on Fish

During the *Northern River Basins Study*, many people were concerned about the impact of industrial discharges on fish health and populations. Most of the traditional food fish in the northern rivers eat other fish or invertebrates. Fish that are at or near the top of the food chain could accumulate pollutants in their tissues. Several NREI studies addressed this, including contaminants in fish tissues and the effects of pulp mill effluents on reproduction.

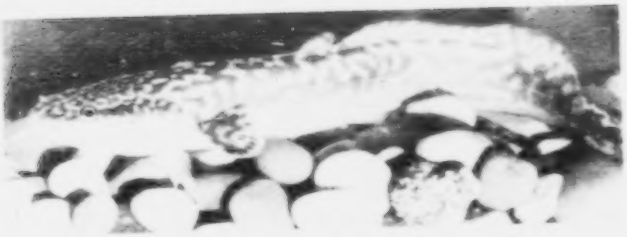
Trends over Space and Time

Spatial and Temporal Trends of Organochlorine Contaminants in Fish from Alberta's Northern Rivers

D. Muir and C. Fraikin

In 1988, dioxins and furans were detected in fish downstream of pulp mills in the upper Athabasca River and in the Wapiti River. The sources of these substances were effluents from mills that were using elemental chlorine for bleaching wood pulp. In the early 1990s, the mills upgraded their effluent treatment systems and eliminated the use of elemental chlorine for bleaching pulp.

In 1994, burbot were collected from 18 sites in the Peace/Smoky/Wapiti river system and Athabasca River basin and their livers analyzed for organic compounds. This survey provided a "snapshot" of spatial trends of persistent chlorinated organics in the Peace-Athabasca basin. Levels of dioxins and furans had declined substantially since 1989, but were still present in burbot livers. An unexpected finding was that levels of PCBs had not declined immediately downstream of the pulp mill at Grande Prairie. As well, PCBs and dioxins and furans were present in higher concentrations immediately downstream of the pulp and paper mills on both the Athabasca and Wapiti rivers than further downstream in the lower sections of the Peace and Athabasca rivers. This suggests that pulp and paper mill effluents were significant sources of PCBs to the rivers. But pulp and paper mills are located near municipalities, which also release various effluents into the river ecosystem. Thus, additional study was required to investigate why the levels of these contaminants are higher immediately downstream of pulp mill and municipal effluents than at more distant sections of the Peace and Athabasca rivers.



Burbot (Wayne Roberts, University of Alberta)

Burbot are top predators and their liver is an ideal tissue for monitoring organic chemicals and mercury. Although their life history is not well studied in most of the Wapiti/Peace-Athabasca system, burbot are relatively sedentary and therefore are good indicators of contaminants in specific areas. As well, burbot liver is a traditional food of First Nations people because of its size and high fat content.

The purpose of this NREI study was to examine trends over time and space of contaminants in fish from the Wapiti/Smoky/Peace and Athabasca river systems, especially in species previously studied (burbot, longnose sucker, mountain whitefish). We thought that levels of dioxins and furans in burbot liver would decline during the 1990s because sources had been eliminated. But PCBs would not, because their sources were likely more diffuse and influenced by urban areas in these watersheds. Results were compared with those from other studies, including from the Slave River below Great Slave Lake.

Adult burbot were collected in fall 1998 from two sites on the Wapiti/Smoky system, three sites on the upper Athabasca River, one site on the lower Athabasca River and one on the Lesser Slave River. Mountain whitefish, bull trout and longnose sucker were also collected at selected sites on the Athabasca. Fisheries staff from Alberta Environment collected burbot from the Peace River in 1999 and from the Wapiti River in September 2000. About 110 burbot and 40 samples of other species of fish were collected. Samples were homogenized and the organic chemicals extracted.

PCBs were the predominant chlorinated organic compounds in burbot liver samples at all locations, while toxaphene and DDT were present at lower concentrations. PCBs were also present in muscle of longnose suckers, mountain whitefish and bull trout. Toxaphene was the main pesticide present in bull trout, whereas DDT and chlordane were the main pesticides in muscles of mountain whitefish and longnose sucker. A few other pesticides were present at very low concentrations in most of these fish species.

Upstream-Downstream Trends: PCB concentrations in burbot and mountain whitefish were much higher immediately downstream of Hinton on the Athabasca River and in burbot below Grande Prairie on the Wapiti River (*Figure 21*). This might imply a source of contamination – likely either the pulp mills or municipal effluent. But the PCB "fingerprint" (i.e., the types of PCBs identified in the fish samples at these sites) suggested that they did not come from widely used PCB products such as Aroclor 1242 or 1254, used in electrical equipment such as fluorescent light ballasts. The reason for this is that the "fingerprint" was similar throughout the basins. In other words, there were no clear "hot spots" which would indicate a specific dumpsite or other source. It seems either that the source is similar throughout the basin, or that the fish are accumulating particular types while excreting other types.

PCB sources likely vary spatially – urban areas influence the river immediately downstream of municipal effluents while atmospheric sources predominate in more remote locations and uninhabited tributaries. PCBs were used extensively in the past. The observed pattern is thus likely to be a combined result of atmospheric deposition and local minor inputs of municipal and industrial effluents, soils, and sediments. A source of PCBs from within the city of Grande Prairie was evident from studies of PCBs in sediments of Bear River, which enters the Wapiti River about 15 km downstream of the municipal and pulp mill effluents. Burbot could move downstream of the inflow of Bear River or into the river itself (*also see Alaee* et al. *p. 76 and Hazewinkel and Noton on p. 78*). The specific source within this area is unknown.

Burbot collected in the Wapiti River downstream of the effluents at Grande Prairie had fattier livers and were generally larger than those upstream. This is likely due to nutrient enrichment of the river, which results in a better food supply for the fish. Higher concentrations of PCBs could be due in part to higher feeding rates and more consumption of fish. But if this were the case, then toxaphene and DDT should be elevated as well, because they have been shown to bioaccumulate to the same or greater extent than PCBs in northern freshwater food webs.

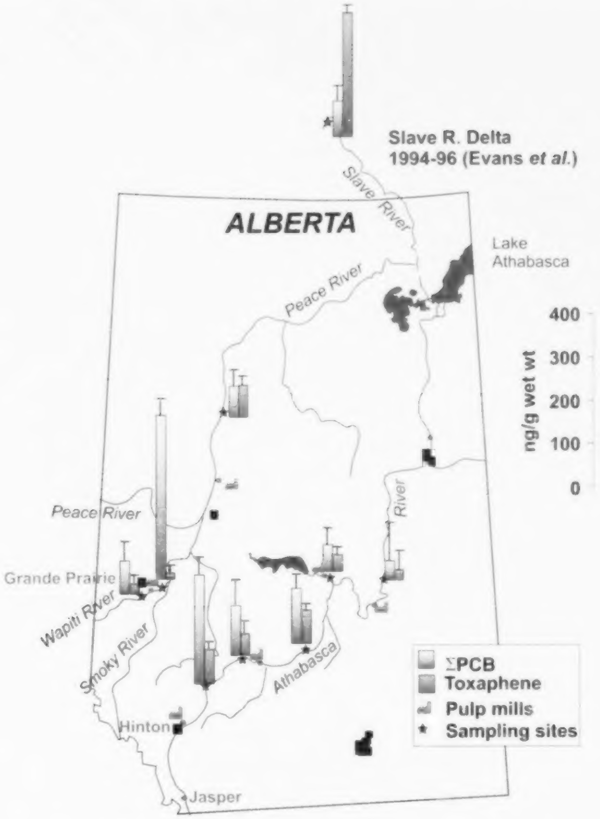


Figure 21. *Spatial trends of PCBs and toxaphene in burbot liver (ng/g wet weight) in the Peace-Athabasca River basin from this study and from a study by M. Evans in 1994-96 on the Great Slave Lake/Slave River.*

The absence of significantly higher concentrations for toxaphene and DDT downstream of Grande Prairie suggests that fish-eating alone cannot explain the higher concentrations of PCB in burbot on the Wapiti or at the site immediately downstream of Hinton. A possible source is minor continuous emissions from the urban/industrial area near the rivers. Compared with other sites, PCB levels in burbot liver are high downstream of Grande Prairie while concentrations upstream are similar to those in Great Slave Lake and the Mackenzie River.

Toxaphene levels throughout the basins imply a diffuse source. Toxaphene was used to eradicate fish in lakes in Jasper Park and elsewhere in Alberta, but was not used agriculturally in Canada. Therefore, the most likely source to the region is from atmospheric deposition in rain and snow or from melting glaciers. Toxaphene has been detected in snow from glaciers in Banff National Park. The slightly higher concentrations in burbot from the Athabasca compared with the Wapiti River could therefore be due to contribution from melting glaciers, which contributes to the flow of the Athabasca in the spring and summer.

The geographical trends of lindane differed from that of other pesticides. Lindane is still used in Canada, although it is scheduled to be phased out in 2004. Its main use is as a seed treatment on canola. The highest concentrations were found in burbot from the Lesser Slave River, the Wapiti River and Great Slave Lake/Slave River. The agricultural use of lindane on canola in the Peace River district and other crop growing areas of northwestern Alberta may explain the observed pattern in burbot.

Other chlorinated organic pesticides, including endosulfan, dieldrin, chlordane and others were present in burbot livers, although at low concentrations. Because most of these are not used in the area, possible sources are atmospheric deposition or glacial meltwater.

Dioxins and furans were detectable in burbot liver from all sampling locations. Average concentrations in burbot were higher at sites downstream from the pulp mills at Hinton and Grande Prairie. Historically, both of these mills used elemental chlorine for bleaching. But since they began using chlorine dioxide in the early 1990s, levels of dioxins and furans have declined in both effluents and fish. Even so, dioxin and furan concentrations were higher in burbot downstream of Hinton on the Athabasca compared with those from the Wapiti. This suggests that there is a greater amount of "legacy" contamination entering the Athabasca at Hinton, which may be due to residues present in some part of the waste treatment system or in bottom sediments in the river. Continued resuspension of contaminated particles can expose fish through the food web.

Trends over time: In previous studies (1992 and 1994) concentrations of PCBs and pesticides were assessed in burbot liver, as well as in muscle samples of mountain whitefish and longnose suckers from the Athabasca/Wapiti/Peace Rivers. This allowed us to compare concentrations from 1992/1994 to 1998/2000 at several locations (*Table 9*). In burbot, significant declines in PCBs were observed in three out of seven locations: in the Wapiti River upstream of Grand Prairie, below Whitecourt on the Athabasca and on the Lesser Slave River downstream of Slave Lake.

Table 9. *Changes in levels of PCBs, dioxins, furans and DDT over time in burbot liver and muscles of mountain whitefish and longnose suckers. No change = nc. Dashed lines indicate insufficient data or not analyzed ↓ = levels decreased.*

Species/Location	Years Sampled	PCBs	DDT	Dioxins	Furans
Burbot Liver					
Athabasca River					
48 km dnst Hinton	1994,1998	nc	nc	↓	↓
300 km dnst Hinton	1994,1998	↓	nc	---	---
Lesser Slave River	1994,1998	↓	nc	↓	↓
Wapiti River					
Upst Grande Prairie	1994,1998	↓	↓	↓	↓
Dnst Grande Prairie	1992,1998	nc	nc	↓	↓
Peace River					
At Notikewin River	1992,1999	nc	---	---	---
Mountain Whitefish Muscle					
Athabasca River					
48 km dnst Hinton	1992,1998	nc	nc	↓	nc
116 km dnst Hinton	1992,1998	nc	↓	↓	↓
Longnose Sucker Muscle					
Athabasca River					
300 km dnst Hinton	1992,1998	↓		↓	↓

Overall, the declines in PCBs were small over the 4 to 7 year period (*Figure 22*). Levels did not decline in burbot livers downstream of Grande Prairie or Hinton. PCBs also declined in mountain whitefish at sites further downstream, but not immediately downstream of the two cities. In longnose suckers, PCBs declined significantly from 1992 to 1998 at the Athabasca River downstream of Whitecourt.

DDT concentrations in burbot liver declined by nearly four times at the upstream site on the Wapiti but not at other sites. DDT did not decline significantly in mountain whitefish collected immediately downstream of Hinton. But significant declines of DDT were found at sites further downstream.

Concentrations of dioxins and furans declined significantly in burbot liver during the mid-1990s from all five locations for which there were comparative data. In the Wapiti River downstream of Grande Prairie, levels of dioxin were 40 times lower in 1998 compared with those from 1992. On the Athabasca River downstream of Hinton, levels declined by nine times between 1994 and 1998.

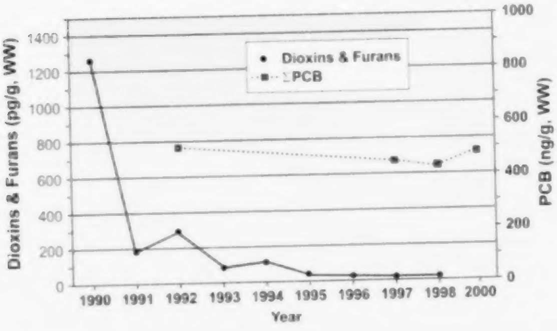


Figure 22. *Average concentration of dioxins and furans and PCBs in burbot liver collected downstream of the pulp mill on the Wapiti River.*

At other locations where pulp mills had not used elemental chlorine for bleaching, e.g., Lesser Slave River, lower concentrations of dioxin were also found but the difference was much less.

This study has documented major declines of dioxins and furans in three species of fish in the Athabasca river system and in burbot near Grande Prairie on the Wapiti River. These substances were associated with contamination of fish by pulp mills using chlorine for bleaching. The declines in dioxins and furans in fish on the Wapiti and the Athabasca demonstrate the success of the program instituted by pulp mills to reduce these substances in their effluent. But PCBs in burbot liver have remained unchanged over an 8-year period downstream of Grande Prairie.

Biomagnification

Contaminant Biomagnification in Specific Reaches of the Peace-Athabasca River Ecoystem - Study Highlights

M.S. Evans and D. Muir

Food chain length is one important factor affecting contaminant levels in fish. Mercury, PCBs and other persistent organic contaminants (such as DDT) biomagnify in food chains. This means that concentrations increase at each feeding level, as shown in Figure 23. When food chains are long, PCB concentrations tend to be high at the top of the chain. Burbot eat forage fish when they are abundant, but also feed on invertebrates when fish prey are scarce. Thus, higher PCB levels in burbot collected downstream of effluents may be related to a greater abundance of forage fish prey than occurs upstream.

Nutrient levels may be a factor as well. In other studies, researchers found that contaminant concentrations were higher in plants and animals where nutrient levels were high. As nutrient levels increase, the amount of algae on rocks increases. This produces an organic film, which more readily accumulates organic pollutants than would occur in nutrient-poor rivers. PCBs are retained in rivers that are rich in attached algae. Thus, benthic invertebrates, which graze on these algae, would be expected to have higher contaminant levels as well.

Stable Isotopes

An atom of a chemical element is made up of protons, neutrons and electrons. The number of protons characterizes the element. For example, nitrogen has 7 protons. But the atomic weight of nitrogen can vary – it can have more or fewer neutrons. Atoms with the same number of protons, but different atomic weights are called isotopes.

Elements can exist in both stable and unstable (radioactive) forms. Most elements of biological interest have two or more stable isotopes. The lightest of these tend to be more abundant than the heavier ones.

In nature, these variations occur because substances (such as minerals, water, and gases) preferentially concentrate one isotope over another, or because organisms can more efficiently use one isotope than another.

In this study, we analyzed algae, detritus, benthic invertebrates and forage fish for organic pollutants and mercury at seven sites investigated by other NREI researchers. Stable isotope ratios of carbon and

Contaminant Accumulation in Larger Fish:

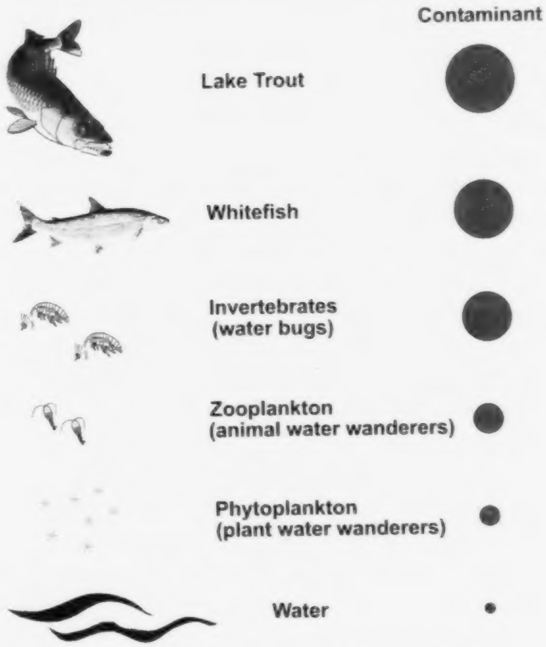

Contaminant
Lake Trout
Whitefish
Invertebrates (water bugs)
Zooplankton (animal water wanderers)
Phytoplankton (plant water wanderers)
Water

Figure 23. *This is an example of biomagnification. A contaminant is taken up from the water by tiny plankton, which are eaten by invertebrates, which are eaten by small fish and then large fish.*

nitrogen were also measured along with basic water quality characteristics. Carbon is measured to assess whether the food web is supported mainly by algae, bits of organic matter or plant material from the land. Nitrogen is measured to assess who is feeding upon whom. For example, a burbot feeding on fish will have a higher nitrogen content than a burbot feeding on plant material.

The study was conducted between August 30 and September 11, 2002. Study sites were similar to those of the burbot liver study (*see Muir and Fraiken, p. 80*). The following sites were sampled:

- Athabasca River at Emerson Lake
- Athabasca River at Highway 947 crossing
- Athabasca River at Fort Assiniboine
- Athabasca River downstream of Calling River
- Wapiti River at Highway 40 upstream of Grande Prairie
- Wapiti River downstream of the Weyerhauser mill effluent
- Smoky River at Highway 34.

Water temperature, pH, conductivity and dissolved oxygen were measured at all sites. A single water sample was collected at each site and later measured for phosphorus, nitrogen, organic carbon and chlorophyll (a measure of the amount of algae). Samples of algae and detritus were collected at each site and analyzed for stable isotopes, mercury and some organic contaminants. Large benthic invertebrates were also analyzed for contaminants. Forage fish were collected by electrofishing. We analyzed about 60 samples of algae, invertebrates and fish for organic pollutants and about 120 samples for mercury and stable isotopes.

One of the consistent observations during the original NRBS and the NREI studies of PCBs in fish is that PCB levels are highly elevated in burbot liver immediately downstream of pulp mills and municipal effluents on the Wapiti and Athabasca rivers but decrease in a downstream direction. One hypothesis for these spatial patterns is that upstream effluents are a major source of PCBs. A second hypothesis is that the burbot collected at the Wapiti site downstream of the effluents and on the Athabasca River at Emerson Lake are eating more fish than those further downstream. This could be expected in these nutrient-rich environments where forage fish should be more abundant because of a greater abundance of invertebrates and algae. The third and most recent hypothesis is that PCBs (and other organochlorine contaminants) are more effectively retained in the nutrient-rich portions of the Athabasca and Wapiti Rivers than downstream.

Our study of PCBs (and other organochlorines) in benthic invertebrates and forage fish provides further insight into these hypotheses. For both types of animals, we saw a spatial pattern in PCBs that was similar to that in burbot liver (*Figure 24*). PCB levels in invertebrates and forage fish decreased from Emerson Lake to Calling River on the Athabasca River and increased from Highway 40 on the Wapiti River to the downstream site. Highest levels were found at the Wapiti downstream site. Overall, this indicates that spatial patterns in PCBs in burbot liver are strongly associated with PCBs levels in forage fish, which are, in turn, associated with PCBs in benthos.

We found few differences in stable isotope values in forage fish along both river courses, suggesting that diets are approximately similar. Forage fish were consuming benthic invertebrates, but lake chub and burbot had a somewhat richer fish diet at the Smoky River site. Despite the higher stable isotope values in the fish at the Smoky River site, their PCB levels were lower than at the Wapiti downstream site. We believe that each type of fish is feeding on a similar diet on all of these rivers. Recent pulp mill monitoring reports have shown that differences were not large in forage fish and invertebrate abundances upstream and downstream of the mills. The benthic community may not use much of the algal growth – the food quality of the algae or poor exposure on rocks may be limiting its use. The Athabasca River between Emerson Lake and Fort Assiniboine and the downstream Wapiti and Smoky sites are productive ecosystems. We believe that the primary reason burbot collected downstream of Grande Prairie and Hinton have higher PCBs in their liver is because their forage fish diet is higher in PCBs, rather than that forage fish are more abundant. PCBs levels are higher in these forage fish because levels are higher in their benthic diet.

We obtained only a few measurements of PCBs levels in algae (Emerson Lake, Highway #947) and detritus (Calling River and Highway 40 on the Wapiti). PCBs levels were fairly high, even in detritus. Algae readily absorb PCBs, and concentrations are similar

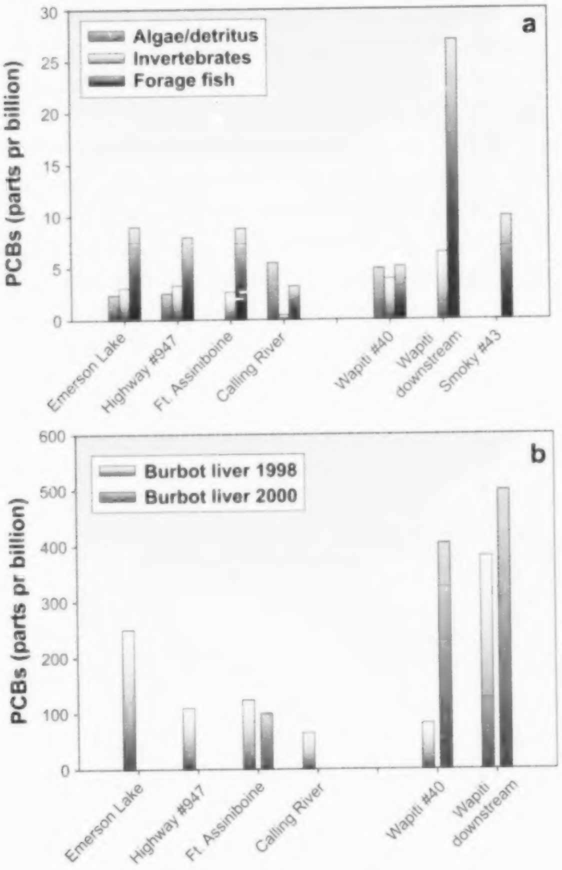


Figure 24. *Average PCB levels in algae, benthic invertebrates and forage fish in the Wapiti and Athabasca rivers (a), and in burbot liver (b).*

to those of benthic invertebrates. PCB levels in detritus exceeded those of benthic invertebrates. Although neither the algae nor the detritus seemed to be a major component of the invertebrate and forage fish diets at the various study sites, they must play an important role in the contaminant spiraling down the river. PCBs that enter the river may become associated with organic matter. As PCBs become attached to organic material, they stay longer in the river ecosystem at those sites. Benthic invertebrates living in this material absorb PCBs. The primary route for invertebrate uptake appears to be from the water rather than the consumption of detritus and algae.

PCB to DDT ratios showed some differences in forage fish and invertebrates along the Athabasca River. However, the greatest differences were in the Wapiti River. Ratios were much higher in benthos at the Highway #40 site than the Athabasca River sites, suggesting PCB enrichment. One possibility is that PCBs came from upstream alpine regions where the low temperatures cause atmospheric PCBs to be deposited with snow. For forage fish, the highest ratio was observed at the Wapiti downstream site. This suggests localized sources of PCBs from the various effluents in this stretch of the river. The data need to be examined more closely to assess spatial trends and causal factors. Some PCB spills have been noted in Grande Prairie so some local sources would be expected.

There was a strong correspondence between spatial patterns in PCB concentrations in benthos, forage fish, and burbot liver on the Wapiti and Athabasca rivers. The reason why PCB levels are higher at the base of the food web at the downstream Wapiti River site and, to a lesser extent, Emerson Lake, cannot be fully resolved in this study. However, we believe the main cause is greater PCB retention in the sections of river rich in algae. It may be that PCBs are retained in fine organic matter flowing downstream and trapped in the bottom where invertebrates live. It is possible that significant quantities of past municipal and pulp mill PCB releases remain trapped in this bottom material.

Endocrine Disruption

Detailed Endocrine Assessments in Wild Fish within the Northern Rivers Basin

M. McMaster, M. Hewitt, G. Tetreault,
J. Parrott, G. Van Der Kraak, C. Portt
and N. Denslow

During the *Northern River Basins Study*, a major issue was the health of resident fish populations. Based on a study of the form and structure of fish gonads and circulating sex steroid levels, there was preliminary evidence of endocrine disruption in fish within the basins. The main concern with this is the potential loss of reproductive capability and therefore declining populations. The following NREI study was designed to address this issue.

The original objective was to determine the extent of endocrine disruption in fish in the northern rivers with our existing endocrine endpoints. These include circulating reproductive sex steroids, changes in sex organ tissue and egg yolk protein in comparison to other measures of growth and reproduction.

Impairment of reproductive fitness in fish exposed to pulp and paper mill effluents represents one of the most well documented cases of wildlife endocrine disruption in Canada. Although some studies documented reproductive effects in fish downstream of effluents, other studies did not. As well, the compounds responsible for the reproductive responses seen at some sites had not been identified.

Endpoints

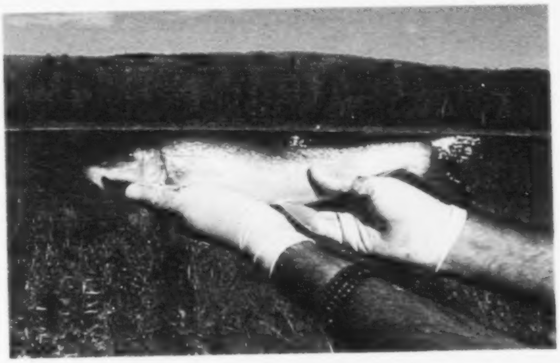
Endpoints are specific measurement or assessment goals. Examples are hormone levels, gonad size and fish growth. An endpoint could also include amount of algae or levels of specific chemicals.

The NREI study was designed with three main objectives:

- To conduct a thorough reproductive endocrine evaluation of wild fish downstream of three modern mills in the northern river basins;
- To conduct laboratory endocrine assays on effluents from a number of pulp mills across Canada to examine the influence of pulp mill treatment technology on endocrine activity in effluent;
- To begin to identify substances in effluent that could function as endocrine disruptors, using bioassay-directed chemical fractionation techniques with wild fish tissues and specific wood furnish.

Our first objective was met by capturing wild fish upstream and downstream of three pulp and paper mills in northern Alberta. These mills were some of the newest, most modern mills in Canada and yet previous studies had suggested that reproductive effects might be present in fish downstream of their effluent discharges. Fish health was examined and compared with a number of reproductive endpoints to assess endocrine function. Fish responded to increased nutrients in effluents by showing signs of higher growth rates, increased fat stores (*Figure 25a*) and gonad development compared with those captured upstream. This was particularly true below the Weyerhaeuser mill at Grande Prairie.

Some signs of altered reproductive function were observed downstream of the mill sites, but also downstream of the municipal sewage treatment plants from the neighboring communities.



Longnose Sucker (NWRI, Environment Canada)

For example, longnose sucker collected downstream of the municipal sewage discharge from Grande Prairie showed alterations in levels of steroid hormones (*Figure 25b*) and egg yolk protein compared with fish collected upstream. Additional reproductive alterations were minimal compared with those in studies conducted at older facilities in Canada. It is not clear, however, whether nutrient enrichment masks other endocrine responses. For example, fish that are in better condition because more food is available may offset depressed reproductive function due to endocrine disruptors in their environment. Results from studies in which caged fish are exposed to effluent may help address some of these questions. Follow-up studies in 2001 showed that there were signs of recovery downstream of the sewage discharge on the Wapiti River after tertiary treatment was implemented at the plant (*Figures 25a and 25b*).

Our second objective was to determine whether effluents from a range of mills across Canada had the potential to alter reproductive endocrine function in fish. This objective was met by collecting effluents from mills with a range of different process and treatment strategies. In the laboratory, effluents were dried, extracted, and tested for their ability to bind to fish sex steroid hormone receptors. Other tests were also run to determine the ability of the effluents to induce liver enzymes, which the fish use to excrete contaminants. As well, we tested for the production of vitellogenin, an egg yolk protein found normally only in female fish.

There were no clear correlations with the type of mill process used or the type of effluent treatment with the endocrine potential of these effluents. Both increases and decreases in endocrine activity were observed after secondary treatment of the effluents.

so it is unclear what effects, if any, conventional effluent treatment is having on levels of hormone-active compounds in the effluents.

All three of the effluents from the mills studied in the wild fish surveys contained compounds that were active in the endocrine assays.

The third objective was to begin to identify effluent constituents functioning as endocrine disruptors. This approach was designed to focus on only those endocrine disrupting substances that are taken up by the fish and incorporated into its body tissues (bioavailable). Effluent mixtures generally contain thousands of unknown compounds. Chemical identification in pulp mill effluent is difficult due to the presence of a number of wood-derived compounds. These compounds are not bioavailable to the fish themselves and interfere with the extraction procedures. As part of this study, we developed a protocol that allows us to start with only the bioavailable compounds. For this, wild fish were caged in effluent, then liver tissue was removed from the fish and used to evaluate what kind of chemicals were accumulated during the caging period.

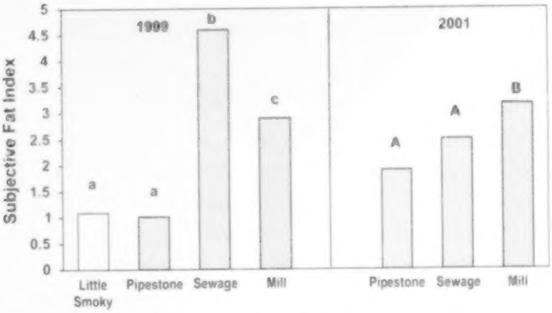


Figure 25a *Fat index for female longnose sucker collected on the Wapiti River in the fall of 1999 and 2001. In 1999 fish collected downstream of the two discharges showed signs of nutrient enrichment (increased fat - higher score) whereas in 2001 fish downstream of the sewage site did not show as large a response.*

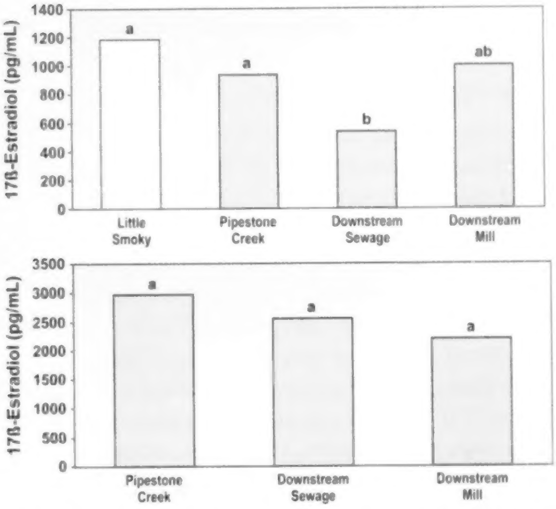


Figure 25b. *Circulating levels of 17β-estradiol in female longnose sucker collected on the Wapiti River in the fall of 1999 and 2001. In 1999 female fish collected downstream of the sewage discharge showed reduced levels, but in 2001 no differences were found after tertiary treatment began.*

We demonstrated patterns of bioavailable substances in both bleached sulfite/groundwood effluent and bleached kraft mill effluent. Both effluents changed the ability of fish to control reproductive hormones. We can now conclude that multiple ligands for fish sex steroid receptors are readily bioavailable to fish. Male steroids persisted in liver tissues after the exposure stopped. In another study, the presence of bioavailable hormone ligands continued after the mill changed its processes, which coincide with the persistence of effects in wild fish.

In another part of the study, wood chips were obtained from the pulp and paper mill in Grande Prairie to begin to identify the compounds responsible for the reproductive effects downstream of the effluent. This mill furnish, which contained 50% white spruce, 47% lodgepole pine and 3% balsam fir, was then extracted and tested using a number of the laboratory endocrine assays (*see Hewitt* et al., *p. 71*).

The detailed endocrine studies conducted on wild fish within the northern basins identified some alterations in reproductive fitness, but these responses were minimal compared with those in some earlier studies conducted at other pulp and paper mills in Canada. It is not known what caused the reduced effects on wild fish reproductive function. Possibilities include the fact that the three mills are generally newer and more modern than previous ones examined or perhaps conditions in the river are protecting fish from these endocrine-active compounds. Fish collected downstream of discharges from both the municipal sewage treatment plants and the pulp and paper mills did demonstrate some responses related to nutrient enrichment. These responses correspond well with recently submitted reports for the *Environmental Effects Monitoring Program* for these three mills. These studies now provide a plausible linkage between effects in wild fish and bioavailable compounds in effluents that can influence sex hormones in fish. There is now excellent potential to investigate the identities of these substances further.

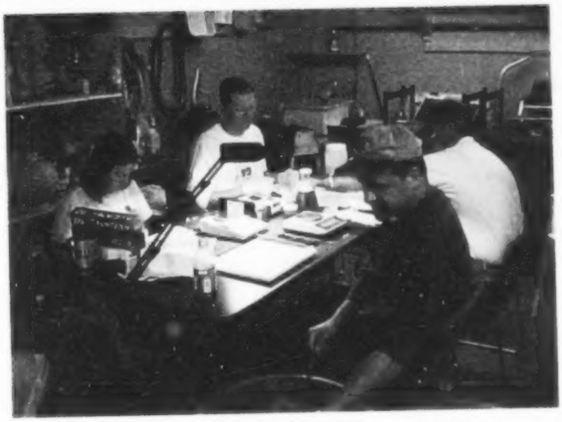
Fish Health

Fish Health Effects from Oil Sands Wastewater Discharges and Naturally Occurring Oil Sands Compounds in the Athabasca River System

J. Parrott, G. Tetreault, M. Colavecchia, M. Hewitt, J. Sherry and M. McMaster

In 1999 we began a joint study with the oil sands industry to develop a picture of fish health in the Athabasca River system. The purpose of this project was to assess the potential for oil sands industrial wastewater discharges to affect fish health. To do this, we first needed to understand the effects of natural oil sands chemicals on fish. With information on the current health of fish in the Athabasca River, we can progress to assessments of new discharges of oil sands tailings waters. The research pairs fish health effects with chemistry of oil sands compounds to identify causative components of the natural and human-caused oil sands waters.

To assess the potential effects of natural oil sands exposure, small fish (slimy sculpin) were sampled from several Athabasca River tributaries upstream and downstream of the oil sands formation. Fish were sampled and dissected to determine growth (length, weight and condition factor), indicators of metabolic health (liver weight) and reproduction (gonad weight, sex steroid levels). In addition to this fish health work, we performed some lab exposures of fish eggs (fathead minnow and native Athabasca white sucker) to selected river sediments and bitumens, and to sediment from Suncor refinery wastewater ponds. This assessed the potential for natural bitumens, river sediments and solids from the refinery pond to affect larval fish survival and growth.



Fish Tissue Work in the Lab (NWRI, Environment Canada)

In autumn of 2000, slimy sculpin from the oil sands mining site on the Steepbank River had decreases in production of sex steroids by gonadal tissue, compared with upstream fish. Decreases were seen in both sexes in most of the sex steroids measured (17β-estradiol, testosterone and 11-ketotestosterone) in ovaries and testes. Decreases in sex steroids indicate fish may be at risk for effects on reproduction in these areas. As well, slimy sculpin showed increased levels of enzymes in their livers at several downstream sites, where there was exposure to oil sands related chemicals and where surface disturbance was occurring. The highest liver enzymes (15 times normal levels) were found in fish captured from river sites close to human activities (mining and surface disturbance). Levels of liver enzymes from fish captured from areas of the river where natural erosion of oil sands contributed chemicals also had high liver enzyme levels (3 times normal levels). But these were not as high as from areas where mining was going on. This indicates that at certain sites on the rivers the fish are being exposed to foreign chemicals. The response of the fish liver is to increase the levels of enzymes in order to break down these chemicals.

Fish Netting (NWRI, Environment Canada)

We tested whether fish eggs could hatch and develop normally when they were exposed to various concentrations of natural sediments from the rivers and to bitumens and sediments from the refinery wastewater pond. Sediments from the refinery wastewater pond were highly toxic to fathead minnow larvae and to Athabasca white sucker larvae. As little as 0.2 to 0.4 g/L caused a dramatic increase in larval deformities (heart edema, yolk sac edema and curved spines). Native white sucker eggs showed similar deformities with exposure to the refinery wastewater pond sediment, but the quantities of sediment required to cause these effects were four times higher. Natural bitumens collected from river sites (Steepbank and Athabasca River) resulted in similar larval mortality and deformities in fathead minnows, but the concentration required to produce responses were about 10 times higher than those from refinery wastewater sediment. Ells River bitumen was highly potent, and tiny amounts caused deformities in some fish larvae. Sediment and solids from the refinery settling pond were very potent in eliciting these responses in larval fish in the lab. However, the eggs/larval fish were also affected by exposure to natural sediments and bitumens. It appears that there are many oil sands related compounds that are natural and can elicit toxicity and deformities in larval fish.

Suncor Experimental Consolidated Tailings Pond (AENV)

Effects of Contaminants on Other Organisms

The Ecological Viability of Constructed Wetlands at SUNCOR: Population and Health-related Considerations in Birds and Amphibians

M. Wayland and J. Smits

Although many people are concerned about fish, other organisms play an important role in healthy ecosystems. Two studies that are summarized below addressed this: one on the toxicity of oil sands tailings ponds on birds, which can be used as indicators of ecosystem health, and the other on impacts of naturally occurring oil sands on benthic invertebrates.

Birds

The recovery of bitumen from oil sands requires a large volume of water. This produces large amounts of tailings water containing clay, sand and unrecovered bitumen. Several constituents of tailings water, such as polycyclic aromatic hydrocarbons (PAHs) and naphthenic acids, are toxic to aquatic organisms. Because of this toxicity, the release of oil sands tailings water into the surrounding natural environment does not presently occur. One of the major challenges facing the oil sands industry is the storage and disposal of these large volumes of water in a way that won't affect the environment. Corporate policy and government regulations require that the reclamation of oil sands mining sites be done in an environmentally acceptable manner. Wetlands are integral components of present reclamation strategies. Wetlands function as buffer zones between reclaimed deposits and off-lease aquatic environments that receive this water. Although the toxicity of tailings water has been described for aquatic animals, no studies have been done on terrestrial vertebrates. In previous research, tree swallows have served as indicators of local contamination – they readily accept nest boxes, come back year after year and forage on aerial insects of aquatic and terrestrial origin within short distances from their nests.

The objectives of the project were to:

- Assess the ecological usefulness of natural and constructed wetlands for remediating oil sands tailings water by focussing on tree swallows as an indicator of the health of the local environment.
- Develop sensitive assessment techniques for examining the health of birds that are likely to use such wetlands – in particular to examine immune function, growth and survival of tree swallow nestlings raised near wetlands, some of which have received oil sands tailing waters.

In 1998, wild nestling tree swallows and semi-captive mallard ducks were the subjects of a study to determine the ecological viability of reclaimed wetlands. Two wetlands received tailings or water from mine tailings ponds on oil sands mine sites. Immune function, reproductive success, nestling growth and survival, and diet of tree swallows were examined. As well, immune response and pathology were investigated in the ducks. One aspect of immune function was assessed in live birds of both species. Reproductive performance was evaluated through clutch size and mass, as well as nestling survival and growth.

We found that there were no differences between reclaimed wetland sites and reference sites for tree swallow reproductive success, nestling growth rate, and immune response. But increased activity of certain enzymes at the remediated sites suggested the presence of oil sands contaminants in the diet of nestlings at those sites.

Another part of the study was to assess the potential for exposure of riparian wildlife to aquatic contaminants associated with oil sands. To do this, it is essential to get information about diet and contaminant concentrations in their food. Therefore, in 1999, collections of sediments as well as aquatic larval and adult stages of wetland-dwelling insects were made at 11 wetlands. Three of these received experimental additions of oil sands tailings or tailings pond water. A fourth was a wetland situated adjacent to the top of the berm that surrounds Tailings Pond 5 at Suncor. The closeness of this wetland to the tailings pond could result in high sediment contaminant levels, because contaminants can move into the air from the tailings pond. It could then be deposited in the adjacent wetland. Seepage from the tailings pond into the wetland could also occur. The remaining seven wetlands were natural wetlands located various distances from active mining sites and tailings ponds.

Analyses of sediment samples and aquatic insects for polycyclic aromatic hydrocarbons (PAHs) were completed. PAHs are formed by incomplete combustion of organic materials and as part of the process by which fossil fuels are formed. As a result of the latter process, PAHs are present in substantial amounts in fossil fuel sources, including oil sands. PAHs are toxic compounds with wide-ranging effects, including some that cause cancer.

Values of PAHs in sediments ranged from below detection limits to > 2000 ng/g dry weight. In larval aquatic insects concentrations ranged up to 19,000 ng/g while in adult insects that had emerged from aquatic environments, concentrations ranged up to 9,800 ng/g. Some types of PAHs were detected at low concentrations, while other types were found at much higher concentrations. Concentrations of PAHs appeared to be higher in wetlands that were affected by tailings.

Our results indicate strong potential for bioaccumulation of sediment-associated PAHs by aquatic insects. These PAHs remain in adult insects after they have emerged from wetlands. The presence of PAHs in adult insects means that birds that eat insects, such as tree swallows, could be exposed to PAHs from remediated wetlands in oil sands impacted areas.

Benthic Invertebrates

Ecological Effects of Natural Releases of Oil Sands Contaminants on Benthic Macroinvertebrates

R. Brua, K. Cash and J. Culp

Our study was designed to assess 1) the impact of naturally occurring PAHs on the density and community composition of benthic invertebrates, and 2) the toxicity of river sediments to benthic invertebrates.

Benthic invertebrates were sampled from the Ells, Steepbank and MacKay rivers, which are major tributaries of the Athabasca River. On each river, an upstream site was outside of the oil sands area and thus acted as a reference. A middle site was adjacent to oil sands formations. A downstream site was also exposed to naturally occurring PAHs. Sediment samples were collected from each of these areas for toxicity testing. Two species of invertebrates were used as test organisms.

This study found that species diversity and numbers were lower in the downstream sites on all three rivers, compared with the middle and upstream sites. The downstream sites have exposures of oil sands which are the source of PAHs in the river sediments. But the composition of the bed materials at these downstream sites was different than at sites further upstream, so this may explain differences in benthic invertebrate populations. Toxicity tests found reduced survival and growth in the downstream section of Ells and Steepbank rivers. This corresponds with the highest PAH levels in these rivers.

Collecting Benthic Invertebrates for Contaminant Analysis from the Wapiti River (AENV)

Other Water Quality Characteristics

Natural water quality characteristics were also studied during NREI. Dissolved oxygen (DO) is a key substance, because low levels can indicate that a river is not healthy. Often, low concentrations of dissolved oxygen may indicate that nutrient levels are high – high concentrations of nutrients (phosphorus and nitrogen) result in abundant plant growth. During the day, these plants photosynthesize and cause DO levels to increase, but at night, plants respire and use oxygen. Then, DO levels can fall dramatically, and cause stress to fish and other animals in the water.

The following studies looked at dissolved oxygen during winter and in the bottom sediments where fish eggs and invertebrates are found. Other papers below deal with nutrients: setting nutrient guidelines for northern rivers and the effects of pulp mill and municipal effluents on plants and animals.

Dissolved Oxygen in Water

Winter Dissolved Oxygen in the Athabasca River

L. Noton

Dissolved oxygen (DO) is one of the most fundamental substances in water. It is essential for living things in rivers. If levels of dissolved oxygen become to low,many types of fish and invertebrates could die. Fish are dependent on invertebrates for food. Thus, it is important to know whether dissolved oxygen levels are adequate to sustain both the benthic invertebrate and fish communities. Winter is a particularly critical time – rivers are under ice, flows are low and plant photosynthesis does not replenish oxygen (*Figure 26*). On the other hand, most cold-blooded animals have lower needs for oxygen when it is cold.

In winter, levels of dissolved oxygen (DO) in the Athabasca River are usually lowest just upstream of Grand Rapids in the Ft. McMurray area. After the

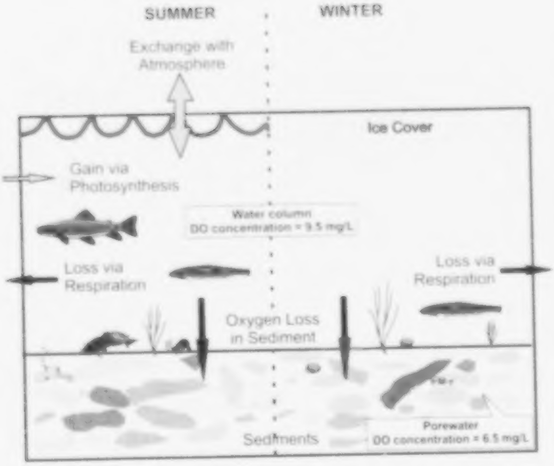


Figure 26. *Gains and losses of oxygen in summer and winter.*

river passes through the rapids it becomes oxygenated, and the highest levels are usually seen downstream of Grand Rapids. Alberta Environment sampled benthic invertebrates upstream and downstream of Grand Rapids to determine the effects of low winter dissolved oxygen levels on the benthic invertebrate community. By comparing the types and number of invertebrates above and below the rapids in winter, we checked to see if there were any effects of low dissolved oxygen.

Sampling of benthic invertebrates and dissolved oxygen was conducted in the Athabasca River during 1998, 1999 and 2002.

Athabasca River at Grand Rapids (AENV)

As well, DO concentrations are monitored every winter upstream of Grand Rapids and at several other locations in the Athabasca River system. Figure 27 shows winter dissolved oxygen levels upstream of Grand Rapids during the winters of 2001 to 2003. In 2003, the lowest DO conditions seen in 13 years of monitoring occurred in late winter. Dissolved oxygen declined below the DO guideline of 6.5 mg/L upstream of Grand Rapids. It remained below the guideline for over a month. Samples of benthic invertebrates were taken again, in March 2003, to provide data for the assessment of this record low DO event; all four years of invertebrate data were subsequently evaluated. Differences were found in the composition and abundance of invertebrates upstream and downstream of Grand Rapids in all four years. Some of this difference appeared attributable to slight differences in physical habitat between the two locations. However, the difference was more significant in 2003: total density and the number of invertebrate types, in the lower DO conditions upstream of the rapids, were significantly less than in the well-oxygenated conditions downstream. This indicates that sustained winter DO concentrations below the 6.5 mg/L chronic guideline can adversely affect invertebrates in the Athabasca River.

Dissolved Oxygen Relationships of Water Column and Pore Water Habitat

J. Culp, N. Glozier, M. Medding, L. Wassenaar, F. Wrona, G. Koehler and D. Halliwell

Dissolved oxygen is an important indicator of aquatic ecosystem health, because fish and aquatic invertebrates need it to grow and breathe. The current *Canadian Council for Ministers of the Environment* (CCME) guideline for dissolved oxygen in rivers states that dissolved oxygen concentrations in the water above the bottom (water column) are not to fall below 6.5 mg/L to protect cold water adult fishes, nor below 9.5 mg/L for other life stages. The CCME guideline, along with other guidelines worldwide, has been adapted from the US EPA guideline for dissolved oxygen. It assumes that as long as dissolved oxygen concentrations in the water column remain above the stated levels, fish and aquatic invertebrates in all habitats are protected.

Pore water dissolved oxygen is important for fish eggs and bottom dwelling animals (fish food). We expect that there would be less dissolved oxygen in the bottom of a river than in the water above the bottom. But the guideline assumes that pore water dissolved oxygen concentrations would fall no more

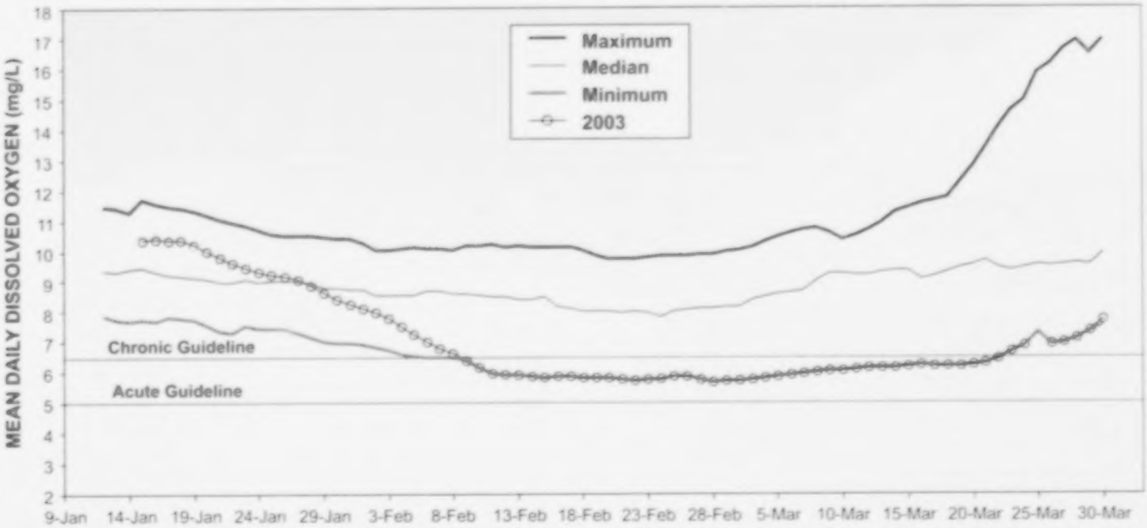


Figure 27. *Winter dissolved oxygen concentrations in the Athabasca River upstream of Grand Rapids, 1989-2003.*

than 3 mg/L below concentrations in the water column. An underlying assumption of the guideline is the existence of a functional relationship between dissolved oxygen in the water column and in the pore water within the bottom material (substrate) in the river. That is, when dissolved oxygen in the water column increases, so does dissolved oxygen in the bottom.

Pore Water

Pore water is the water in between individual grains of sediment or gravel in a river bottom.

The primary goal of the NREI project on dissolved oxygen (DO) was to assess whether the current CCME guideline of 6.5 mg/L will adequately protect fish and other aquatic life in northern Canadian rivers. To do this, we investigated the relationship between water column and pore water dissolved oxygen concentrations in northern river basins. Study questions included:

- Is the integrity of pore water within the river substrate protected by water column dissolved oxygen guidelines? Can we safely assume that the difference between pore water dissolved oxygen and water column dissolved oxygen is 3 mg/L or less?
- Is there a harmful effect of effluents from municipal sewage plants and pulp and paper mills on pore water dissolved oxygen concentrations below outfalls? Is there a cumulative effect from effluents, which would cause DO concentrations to decline further?
- What is the functional relationship between dissolved oxygen and river characteristics? What are the processes that impact the dissolved oxygen balance in the water column and substrate of northern rivers?
- Does the CCME dissolved oxygen guideline of 6.5 mg/L protect aquatic organisms living in northern rivers?

To address these questions, several studies were conducted on the Wapiti River. Dissolved oxygen concentrations were measured in the water column and in the pore water at sites above and below effluent discharges. River characteristics were measured to determine whether pore water dissolved oxygen concentrations could be predicted based on substrate composition, flow velocity, etc. As well, stable isotopes (^{18}Oxygen) were measured to assess ratios of DO exchange and whether and how DO is being consumed in the river bottom.

Three study sites were sampled on the Wapiti River during three consecutive winters (March 1999-2001). A reference site was located upstream of Grande Prairie – it was assumed this site was not impacted by effluents, and therefore represents the natural condition. Another site was located 5 km downstream of Grande Prairie's treated sewage effluent. The third site was located 27 km downstream of the Weyerhaueser pulp mill effluent. Dissolved oxygen levels were measured and routine chemistry samples were collected from the water column and the pore water (at about 5-10 cm into the substrate). Depth of snow, ice and water were recorded, as were water velocity, substrate type and water temperature.

Dissolved oxygen concentrations in the pore water were highly variable and ranged between 0.27 and 13.28 mg/L, whereas water column DO concentrations varied little (10.25-13.60 mg/L). Across all sites, DO concentrations were significantly lower in pore waters than in the water column (*Figure 28*). Comparison between the three sites indicates that pore water DO concentrations are depressed to a significantly greater extent in the section of river receiving both sewage and pulp mill effluents compared with the two upstream sections that received no discharges or only the sewage effluent.

The difference between water column and pore water DO in the Wapiti River was also significantly greater than the 3 mg/L guideline. Differences ranging between 9 mg/L and 12 mg/L were commonly recorded. This observation was true for both reference and effluent-affected sites.

A strong positive relationship between water column and pore water DO is implicitly assumed by regulatory agencies. But on the Wapiti River, we observed only a poor functional relationship between water column and pore water DO at all the sampling sites. Water column DO is clearly a poor predictor of pore water concentrations. Physical conditions such as water velocity, depth and type of substrate could be used to predict pore water DO. At potentially impacted sites, other conditions such as the concentration of dissolved organic carbon, may need to be included. However, an effective tool for predicting pore water DO is lacking.

This study suggests that it is not valid to assume that water column and pore water dissolved oxygen are related, nor that the difference between pore water and water column DO is less than 3 mg/L. Pore water DO is influenced by cumulative inputs of effluents, increasing the proportion of sites with pore water DO concentrations of less than 6.5 mg/L. But the ecological relevance of these reductions is unknown. At sites of concern, we might consider monitoring pore water DO directly, and compare this to reference conditions. Thus, guidelines could be established based on pore water DO at particular reference sites. Some agencies are moving in this direction, but guidelines are still based on water column DO. As well, critical fisheries habitat could be mapped and stable isotopes used to identify the relative importance of processes affecting dissolved oxygen concentrations.

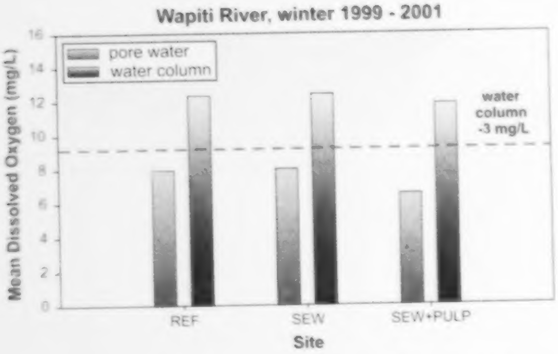


Figure 28. *Average water column and pore water dissolved oxygen concentrations at three sites in the Wapiti River. Dashed line indicates the average water column dissolved oxygen level minus 3 mg/L.*

Nutrients

Setting Nutrient Guidelines for the Northern Rivers of Alberta

P. Chambers and M. Guy

Nutrients are substances that plants need for their growth. They include nitrogen, phosphorus and potassium – the same substances that people use for fertilizer. Without them, plants wouldn't grow and there would be no fish, fish food or other aquatic life. But large amounts of nutrients entering a river or lake can be harmful. The addition of nutrients to rivers can result in nuisance growth of aquatic vegetation, increased oxygen consumption and changes in populations of aquatic animals, including fish. An increase in nutrients in a water body is called eutrophication (*see p. 96*).

Studies conducted during the *Northern River Basins Study* (NRBS) reported high nitrogen and phosphorus concentrations in the Athabasca River downstream of Jasper, Hinton, Whitecourt and Fort McMurray and in the Wapiti River downstream of Grande Prairie. In these areas, the quantity of benthic algae and the density of invertebrates were also high. The studies also identified the need for nutrient guidelines for specific sections of the northern rivers. As well, the studies raised questions about the relationship between river nutrient concentrations and plant abundance.

Eutrophication

Eutrophication is an increase in the phosphorus or nitrogen supply to a river or lake – this results in increased plant growth, which may cause fluctuations in levels of dissolved oxygen and changes in the types of plants and animals living there.

The aim of the NREI study was to propose guidelines for nutrients in certain sections of the northern rivers to minimize eutrophication. Once guidelines are set, municipalities and industries can work toward reducing nutrient inputs to the rivers. But these guidelines must be based on relating actual changes in levels of nutrients to responses by aquatic life. For this, we have to know the reference conditions of a particular river.

We analyzed 15 years of water quality and algae data obtained from Alberta Environment, Environment Canada, pulp mills and projects conducted as part of NRBS. To minimize the natural variability in background nutrient concentrations and the responses of plants and animals, the data were grouped into ecoregions:

- Montane (mountain) - the Athabasca River from the most upstream site (Athabasca Falls) to 9 km upstream of Hinton.
- The Lower Foothills - upstream of Hinton to 50 km upstream of Whitecourt on the Athabasca River.
- The Central Mixedwood - the lower 1085 km of the Athabasca River.
- The Dry Mixedwood - the Wapiti River from Redwillow Creek to its mouth.

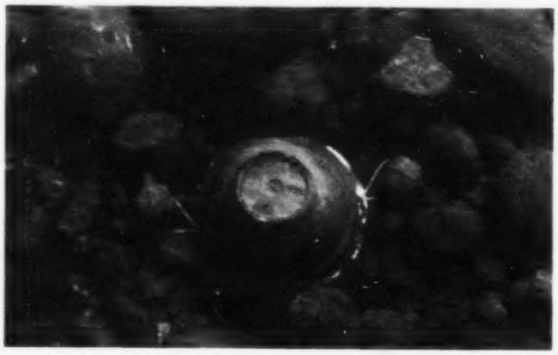
Nitrogen (N) and phosphorus (P) concentrations for background conditions were established for each of the ecoregions. Background phosphorus concentrations ranged from 5 to 22 micrograms per litre (μg/L) total P and 2 to 8 μg/L total dissolved P for the Athabasca River. The concentrations increased from the Montane to the Lower Foothills to the Central Mixedwood ecoregions. Background nitrogen concentrations also increased from the Montane to the Central Mixedwood ecoregion.

We looked at several approaches for setting nutrient guidelines for the northern rivers. Our approach resulted in concentrations of nitrogen and phosphorus for the Montane and Foothills ecoregions that were similar to recommended guidelines for similar areas in the United States, Australia and New Zealand: 10 μg/L total P and 120 μg/L total N. The values are also similar to those identified from an analysis of more than 200 world rivers as the boundary between low and moderate nutrient levels.

After we identified background conditions for the four ecoregions in the upper portion of the Alberta northern river basins, we next looked at the effects of nitrogen and phosphorus on quantities of benthic algae. The purpose of this was to determine:

- Which nutrient controls algal abundance at reference sites, and
- How much the quantity of algae will change as levels of nutrients in the river increase or decrease.

For the Montane and Lower Foothills ecoregions, we conducted experiments by adding P, N or both to artificial channels set up on the riverbank and by placing sealed clay pots (containing P, N or both) in the river (*see photo*). Then algal growth in the channels and on the pots was measured. We confirmed that phosphorus is the nutrient controlling benthic algal abundance in these ecoregions. This means that if phosphorus inputs increase, benthic algal growth will also increase. But if only nitrogen was added, there would be little increase in algae.



Clay Pots Used for Nutrient Studies (NWRI, Env. Canada)

For the Dry Mixedwood ecoregion, a variety of measurements and experiments showed that both N and P control the growth of benthic algae in the Wapiti River. This means that benthic algal growth increases only when both phosphorus and nitrogen inputs increase. Experiments to identify the nutrient(s) controlling algal abundance have not been conducted for the Central Mixedwood ecoregion.

Table 10 shows the proposed guidelines for nutrients and chlorophyll. These were calculated as the 75th percentile of data from reference sites.

Models have been developed that show how algal abundance changes in response to phosphorus and nitrogen inputs. Benthic algae in the four ecoregions differ in their relationship with nutrients. As well, river flow volume and turbidity are significant factors that negatively affect algal abundance.

This research showed that concentrations of phosphorus and nitrogen and levels of benthic algae could be used to characterize the four ecoregions that make up the southern portion of the Alberta northern river basins. Results from in-river observation and experimentation showed that phosphorus is the nutrient controlling benthic algal abundance in the Montane and Lower Foothills ecoregions. Algal growth in the Dry Mixedwood ecoregion is determined by both N and P. This new knowledge will assist in protecting these northern rivers in their natural state.

Mesocosm Assessment of Pulp Mill and Municipal Sewage Effluent Effects on Benthic Food Webs and Longnose Dace (Rhinichthys cataractae) of the Wapiti River, AB

J.M. Culp, M.G. Dube, K. Cash, N. Glozier, D. Maclatchy and B. Brua

One of the most promising applications of mesocosm technology involves its ability to separate effects of complex effluent mixtures and to examine their impacts individually, in combination, and over a range of concentrations. Natural river substrates can be used in them to look at effects on bottom-dwelling invertebrates. The mesocosm approach is scientifically rigorous – experiments can be done over and over, and one or more of the treatment containers are left untreated to simulate conditions upstream of effluents. This assessment approach has been accepted as alternative to standard environmental effects monitoring to assess pulp mill effects for sites where data are hard to interpret due to multiple point and non-point sources of contaminants. Mesocosms were used in the Wapiti River to assess impacts of sewage and pulp mill effluents on fish, invertebrates and algae.

Fish. The Wapiti River near Grande Prairie, Alberta is exposed to both treated municipal sewage effluent and to effluent from the Weyerhaeuser pulp mill. The primary objective in this part of the project was to evaluate the individual and combined impacts of municipal and pulp mill effluents on juvenile and adult longnose dace. Results from previous environmental effects monitoring at this mill indicated effects on longnose sucker and longnose dace, which resulted largely from nutrient enrichment.

Table 10. *Proposed guidelines for total phosphorus (TP), dissolved phosphorus (TDP), total nitrogen (TN), kjeldahl nitrogen (TKN), nitrite+nitrate nitrogen (NO$_2$+NO$_3$), ammonia (NH$_4$) and benthic chlorophyll a (chla) in micrograms per litre or milligrams per square metre.*

Ecoregion	TP (µg/L)	TDP (µg/L)	TN (µg/L)	TKN (µg/L)	$NO_2 + NO_3$ (µg/L)	NH_4^+ (µg/L)	Chla (mg/m^2)
Montane	17	2	nd	nd	100	9	26
Lower Foothills	27	3	269	200	105	20	45
Central Mixedwood	51	15	553	440	137	40	46
Dry Mixedwood	30	3	292	261	55	10	19

The initial enrichment in the river occurs with the sewage discharge and the second enrichment with the pulp mill discharge. Effects were observed downstream of both discharges. But the presence of the sewage discharge makes it impossible to use field studies to determine the effects of the pulp mill. Therefore, we used mesocosms to assess the effects of the individual effluents in isolation and in combination.

Six treatments were created in the mesocosm stream tanks (*Figure 29*):

- Numbers 1 and 2 had river water drawn from upstream of the municipal discharge to act as controls.
- Number 3 had 1% sewage effluent plus upstream river water.
- Numbers 4 and 5 had pulp mill effluent at 3% and 10% plus upstream river water.
- Number 6 had sewage effluent at 1%, pulp mill effluent at 3% plus upstream river water.

There were five replicate streams per treatment for a total of 30 experimental tanks. Two sets of control treatments were created to maximize our understanding of natural variability in unexposed animals. Comparisons among controls and the two strengths of pulp mill effluent provided an opportunity to evaluate the effects of the pulp mills in isolation under environmentally relevant (3%) and worst case (10%) discharge scenarios. We compared controls, sewage, and the mix of municipal and pulp mill effluent treatments to evaluate the effects of the sewage in isolation as well as the combined effects of the two effluents. This comparison represented the current river situation, with the approximate proportions of these effluents actually in the river.

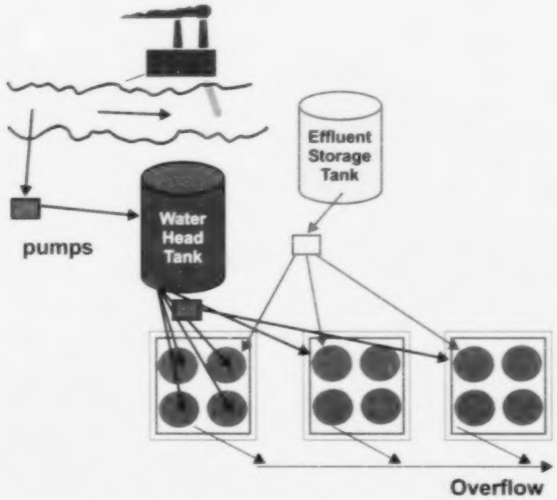


Figure 29. *Basic requirements for a mesocosm experiment. This diagram shows three sets of four tanks.*

Longnose dace from an upstream reference area were captured and their length and weight measured. Thirteen adult and 10 juvenile dace were randomly assigned to each mesocosm tank. This represented 65 adult and 50 juvenile dace per treatment. Fish were exposed for 42 days from August 14 to Sept 25, 2001. At the end of the exposure period, survival, growth, condition, and liver size were assessed in the juvenile fish. Adults were assessed for survival, growth, condition, liver and gonad size, number of eggs and egg size (females), reproductive hormone levels, plasma testosterone (both sexes), 11-ketotestosterone (males only), 17ß-estradiol (females only), and gonad development by tissue analyses.

Pulp mill effluent had no effect on the survival of dace, or on the weight, length or relative liver size of juvenile dace. But there was a difference in the condition of juveniles among treatments. The condition of juveniles exposed to 10% pulp mill effluent was significantly poorer than that of control fish (i.e. the weight was lower relative to the length). In addition, fish exposed to 3% pulp mill effluent had significantly better condition than controls. This suggests a possible nutrient enrichment effect of the effluent on juvenile condition at lower effluent concentrations and a potentially negative effect at higher concentrations.

Pulp mill effluent exposure did not affect the weight, length, liver size, gonad size, condition, gonad development, or plasma testosterone levels in male longnose dace. But males exposed to 10% pulp mill effluent had significantly depressed levels of 11-ketotestosterone, compared with males in control and 3% treatments. This is the male reproductive hormone primarily responsible for development of secondary sexual characteristics such as spawning behavior and breeding tubercles. The significance of these depressed hormone levels is not known. There were also no effects of pulp mill effluent exposure on the weight, length, liver size, gonad size, condition, gonad development, fecundity, egg size, or plasma 17ß-estradiol levels in female longnose dace.

17ß estradiol is a hormone responsible for developing yolk protein in eggs. However, plasma testosterone levels were significantly increased in females exposed to 10% effluent relative to control fish.

Exposure to the municipal sewage effluent decreased male gonad size, depressed plasma levels of 11-ketotestosterone in males, and increased plasma testosterone in females. Exposure to the pulp mill/sewage mixture increased juvenile condition and the number of eggs produced per female.

These results showed that exposure to 10% pulp mill effluent had the potential to reduce juvenile condition in longnose dace and alter some reproductive hormone levels in adult males and females. Exposure to 3% pulp mill effluent increased juvenile condition, which suggests nutrient enrichment at lower effluent concentrations. Municipal sewage effluent affected reproductive endpoints such as male gonad size and some hormone levels in males and females. These results are similar to those reported in the EEM report for this mill, and support the hypothesis that the response patterns in fish are different for the sewage and pulp mill discharges.

Food Webs. Mesocosm experiments were set up to assess pulp mill and sewage effluents on algae, invertebrate animals and fish. Methods were similar to those in the fish experiments above, except that the study included one set of treatments that examined effects on a 2-level food web (algae→invertebrates) and an additional treatment set that evaluated effects on a 3-level food web (algae→invertebrates→fish). We used five treatments for the two-level sets: control, 1% sewage effluent, 3% pulp mill effluent, 1% sewage + 3% pulp and 10% pulp. Measurement endpoints for the two-level food web experiments included algal biomass, invertebrate community composition and insect emergence. The three-level food web experiment included these endpoints and young-of-the-year slimy sculpin. Two treatments were run for the three-level experiments (1% municipal sewage effluent and 1% sewage + 3% pulp mill effluent). Both experiments were 30 days in duration.

Adult insects were collected from emergence traps placed over each mesocosm stream, and benthic invertebrates were collected at the end of the experiment by washing the entire contents of each stream through a fine sieve. Chlorophyll *a* was measured by collecting algae from stones in each replicate stream at the end of the experiment. Sculpin were counted, weighed and the total length measured at the end of the experiment. Weekly grab samples of reference water and the various treatment levels were collected and analyzed for nutrients and general water quality.

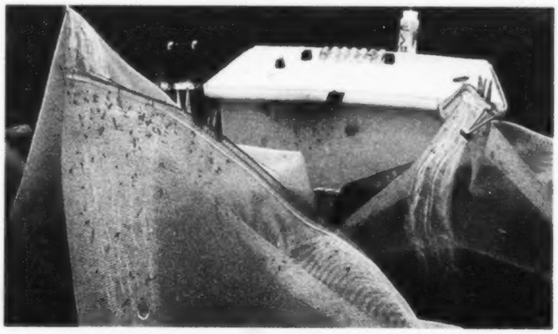
Nutrient concentrations varied across treatment levels. The controls had the lowest levels of dissolved phosphorus and organic carbon, while the highest was in the 10% pulp mill effluent treatment tank. Concentrations of these nutrients increased with increasing effluent concentrations. In contrast, nitrogen concentrations were significantly higher in treatment tanks containing sewage effluent. These results suggest that municipal sewage effluent is an important source of nitrogen for the Wapiti River, whereas pulp mill effluent is an important source of phosphorus and organic carbon.

Algal biomass increased significantly in all treatment tanks relative to the controls and chlorophyll *a* concentrations in all effluent tanks exceeded the proposed Canadian Ecosystem Health guideline of 100 mg/m^2. Preliminary results suggest that algal biomass was more strongly related to nitrogen concentrations than to phosphorus or carbon. The relationship of algal biomass to nutrient concentrations is the subject of a follow-up study currently underway.

Each of the tanks had net traps over them to catch insects as they changed from aquatic immature stages to flying adults (insect emergence). The use of emergence traps allows for measures of total production over the course of the experiment rather than simply measuring standing crop at the end of the exposure period. Insect emergence was dominated by midges (a type of non-biting fly) and was significantly higher from all effluent treatment tanks relative to the controls. Interestingly, the combined total emergence from both 1% sewage and 3% pulp mill tanks was only 60% of that from the tanks containing the combined mixture. These results suggest the possibility that combining effluents produces an enhanced effect on insect emergence. Thus, a cumulative effects approach is important in assessing effluent impacts on aquatic plants and animals. Sculpin exposed to both pulp mill and sewage tended to show slightly higher growth and survival relative to those exposed only to sewage effluent.

The application of the mesocosm approach to the Wapiti River represents the first time this system has been used in a true cumulative effects assessment of multiple effluents. The results indicate that both municipal and pulp mill effluents are significant sources of nutrients to the river. The sewage effluent is important as a source of nitrogen, while pulp mill effluent is an important source of phosphorus and carbon. Our results suggest that algal biomass increases with greater proportions of effluent and is more strongly related to nitrogen than to phosphorus or carbon, suggesting nitrogen limitation downstream of the city of Grande Prairie.

Although algae and benthic insects appear to be strongly affected by sewage and pulp mill effluents and combinations of the two, young-of-the-year sculpin (at least over the duration of the experiment) appeared little affected by effluent exposure. These results are consistent with the findings for longnose dace and indicate that the impact of exposure to complex effluents on aquatic plants and animals is dependent on the species involved. As well, it is likely to vary among food web components. Mesocosms are a technique that allows us to collect quantifiable and reproducible data on cumulative impacts of multiple stressors for different levels of organization within aquatic systems.



Emergence Collection (Environment Canada)

Forest Biodiversity

A major challenge for the environment in the twenty-first century is to conserve *biodiversity* – the variety of organisms. Human alteration of habitat is the single greatest threat to biodiversity around the world. Human activities can influence the distribution and abundance of species, and ultimately whether or not a particular population or community will survive.

The boreal forest is home to a great many species. Birds are a group that has been used to indicate forest condition. Many of these migrate from tropical areas to breed. Several researchers suggest that commercial forest harvest is having the greatest effect on birds in the boreal region.

Because much of the northern watersheds are forested, the NREI looked at several aspects of the impacts of forest harvesting on biodiversity.

Ecological Basis for Stand Management: A Summary and Synthesis of Ecological Responses to Wildfires and Harvesting

S.J. Song, editor

The *Ecological Basis for Stand Management* project was designed to provide science-based information to support the review and evaluation of harvesting practices in boreal mixedwood forests. We used existing literature and data from studies conducted throughout the boreal forest to document and compare ecological responses to wildfire and harvesting at the stand level. This was done for a range of forest ages, from immediately after disturbance through old-growth forests (more than 125 years after disturbance). We also summarized existing information on the responses of plants and animals to riparian areas (those next to water bodies) and forest edges. Through this work, gaps in knowledge were identified and recommendations were derived for forest management context.

The following is a summary of management recommendations from the study:

Management of live and dead residual trees. Retention of live (and dead) residual trees during harvesting increases the variability of vegetation structure over time, and provides older forest habitat within younger forests. Residual patches also provide a source of downed woody material such as snags and logs, that is lacking in clearcut harvested blocks. To emulate natural disturbance, the average percentage of residuals maintained over the forest landscape will need to increase for many harvest operators (above 10%). The range of variation in this percentage should also be extended.

Comparing Old Growth...and Harvest Conditions (Dr. Steve Bradbury, ARC)

Retention of early post-fire stands. Early post-fire stands contain unique biological communities owing to the high percentage of standing, burned, dead trees, the high variability of habitats, and later, large amounts of downed woody material as dead trees fall over. No models for tree harvesting can emulate the structural dynamics of early post-fire. A portion of these post-fire stands should be excluded from salvage logging operations and fire dynamics should be maintained on the forested land base.

Retention of deadwood resources. The high quantity of downed woody material (logs, sticks, twigs, etc.) found in post-fire stands, with the large input of material at about 11-26 year post-fire is different from both clearcut harvested stands and harvested stands containing residual trees. Large diameter logs (greater than 20 cm diameter) that are very decayed create unique microclimatic conditions. They are an important seedbed for a variety of annual and biennial plants, and for mosses and lichens that live on trees and the ground. Downed woody material is important immediately after disturbance for the recolonisation of harvested cutblocks by small mammals. The difference between harvest and wildfire stands highlights a potential problem of long-term carbon loss from soils that may escalate over successive rotations of harvesting.

Retention of old-growth stands of trees. Old growth forests (at least 125 years after disturbance), with large diameter live and dead trees, canopy gaps, large standing dead trees, and large fallen dead trees, provide a highly varied habitat for many species, both horizontally and vertically across the stand. Compared with any forest age, old growth forests have:

- The highest diversity (number of species) and numbers of forest birds.
- The highest number of species for many plant communities, including annual-biennial and perennial plants, low and tall shrubs, tree-dwelling mosses and lichens.
- The highest numbers of small mammals, arboreal mammals (such as northern flying squirrels), mustelids (such as weasels and martins), deer and caribou.

Maintaining the variability of habitats that is represented within these older forest stands is a challenge for forest managers. Retaining individual trees and patches of trees can address some concerns. But the habitat variability across old growth forests, combined with the large territory requirements of some of the species found here, means that forest managers should maintain some large tracts of old growth forest. A variety of strategies can be employed, such as extending the time interval between harvests, retaining large sections of forest with skipped harvests and protected areas with old forest tracts.

Need to recognize and address major knowledge gaps. Research is needed in the following areas at both the stand and landscape level for both wildfire and harvesting:

- Ecological dynamics of retained forest patches through time
- Ecological role and dynamics of non-commercial tree species and stands
- Ecological dynamics of downed woody material
- Ecological effects of salvage logging
- Reproductive and demographic response data for vertebrate systems
- Ecological effects on predator-prey dynamics

- Knowledge on systems not included in this review (arthropods, amphibians, hawks and owls, shorebirds, rare species, etc.)
- Ecological role and dynamics of riparian areas and forest edges
- Long term ecological studies that include variation over space and time at a variety of scales.

Emphasis of active adaptive management approach to forest management. We recommend the adoption of a carefully planned, experimental approach to implementing forest management strategies. The active adaptive management approach explicitly acknowledges our lack of knowledge in and the uncertainty in forest management outcomes, and creates management plans that allow for learning while managing.

Forest management on public lands must involve the public. Managing forests for ecological sustainability reflects the desires of many Canadians. Simultaneously, Canadians have a range of competing and complementary social, cultural and economic values connected to forests that must be explicitly acknowledged. We encourage government and industry to continue to develop appropriate and meaningful forums for this discussion between forest managers and public stakeholders.

Residual Trees (Dr. Steve Bradbury, ARC)

Large-scale Conversion of Forest to Agriculture in the Boreal Plains of Saskatchewan

Hobson, Keith, E.M. Bayne
and S.L. Van Wilgenburg

Changes in the boreal forest of western Canada due to logging, road construction, mining, conversion to agriculture and oil and gas development, act in a cumulative fashion to influence the wildlife inhabiting this ecosystem. Birds are a major component of the vertebrate biodiversity of the boreal forest and the majority of species are protected under federal legislation. As part of an upland component of the NREI, we sought to evaluate how forest loss and fragmentation due to agricultural conversion in the forest fringe region of our area influences forest birds.

Despite widespread recognition of the importance of forest loss and fragmentation on biodiversity, the extent and rate of forest loss even in temperate regions remains poorly understood. We documented forest loss and assessed whether road density, rural developments, land quality for agriculture, and land ownership influenced the distribution and rate of change in forest cover for the entire boreal transition zone (49,846 km^2) of Saskatchewan. This area was completely forested before European settlement. We used the Canadian Land Inventory database and Landsat thematic mapper data to study changes between 1966 and 1994 (*Figure 30*). Forest covered 17,873 km^2 of the study area in 1966 and 13,504 km^2 in 1994. An overall conversion of 73% of the boreal transition zone in Saskatchewan to agriculture has occurred since European settlement. Over the last 28 years, the annual deforestation rate was 0.89%, a rate approximately 3 times the world average. Less forest remained on lands that: 1) were privately owned; 2) had soils with high suitability for agriculture; 3) had high road density; and 4) were in the southern portions of the study area. As well, areas of remaining forest tended to be spatially clustered. Deforestation was more likely to occur on privately owned lands than those managed by the provincial government. Even though changes to forested areas in the Boreal Transition zone were dramatic, no programs are in place to reduce deforestation, despite the importance of this area to a wide variety of forest-dwelling wildlife.

Rapid deforestation due to agricultural expansion is a major threat to bird biodiversity in the boreal forest of western Canada. We surveyed birds along a gradient of forest loss and fragmentation to:

- Evaluate whether bird communities changed in a linear fashion with forest loss or if there was evidence of non-linear thresholds (points at which the rate of change suddenly increases or decreases);
- Determine the relative importance of forest cover and configuration as factors influencing the distribution of forest birds; and
- Test whether the importance of forest configuration increased after thresholds were reached.

In 1999 and 2000, we used *Breeding Bird Survey* methods to collect data on bird communities in 237 landscapes. Each landscape consisted of 10 survey stops within a route. Forest cover ranged from 0.5% to 95%. As well, a configuration index of how forest patches were distributed over the landscape was generated. This was independent of forest cover, and was based on average forest patch size, number of forest patches, and total forest edge. Richness, diversity, and community similarity of forest specialists and habitat generalists showed strong evidence of community changes at 20 to 30% forest cover. That is, these factors declined much more steeply below this threshold. Overall, 65% of the species showed evidence of this change when the amount of forest cover dropped below 30%. There was little evidence of configuration effects for most species (91% of 68 species showed no effects) or forest composition. Configuration did not increase in importance when we examined only those landscapes below thresholds of 30% and 60% forest cover. We conclude:

- Forest cover had the largest influence on the composition of the songbird community,
- Birds typically responded to forest cover in a non-linear fashion;
- Forest configuration did not have a strong effect on the distribution of most bird species;

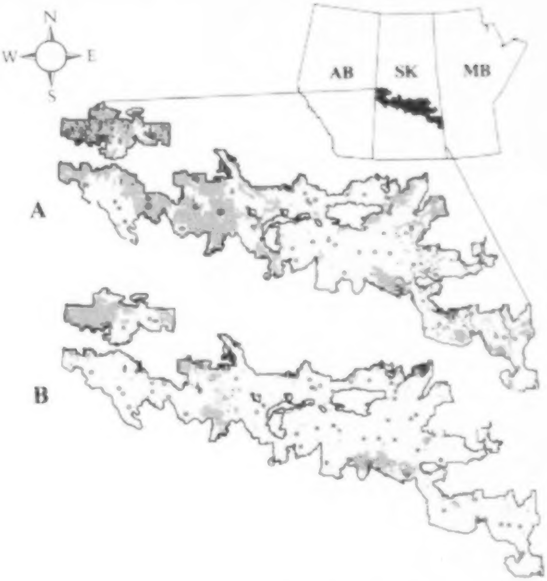


Figure 30. *Amounts of boreal forest in 1966 (A) and 1994 (B) in south-central Saskatchewan. All towns of >100 people are shown as red dots.*

We examined North American Breeding Bird Survey data for three routes impacted by local forest habitat loss and fragmentation and one route located (as a control) in contiguous forest, to determine how changes in land use influenced the relative abundance and diversity of bird species. Over the 18-year history of one of the impacted routes, species diversity declined from a maximum of 105 species in 1987 to 67 species by 1995 (*Figure 31*). In addition, 43 species that were regularly recorded before 1990 disappeared after that, and 13 other species showed significant negative population trends. This pattern was also seen on the other impacted routes – eight species on each route showed significant negative population trends between the 1970s and the 1990s. Forest, grassland and wetland species of birds all declined. In contrast, none of the species on the forested control route showed significant population declines. We conclude that habitat loss, primarily due to forest clearing for agriculture in the forest fringe region of the Canadian prairies, has contributed to the decline of many species and disappearance of others on many breeding bird survey routes.

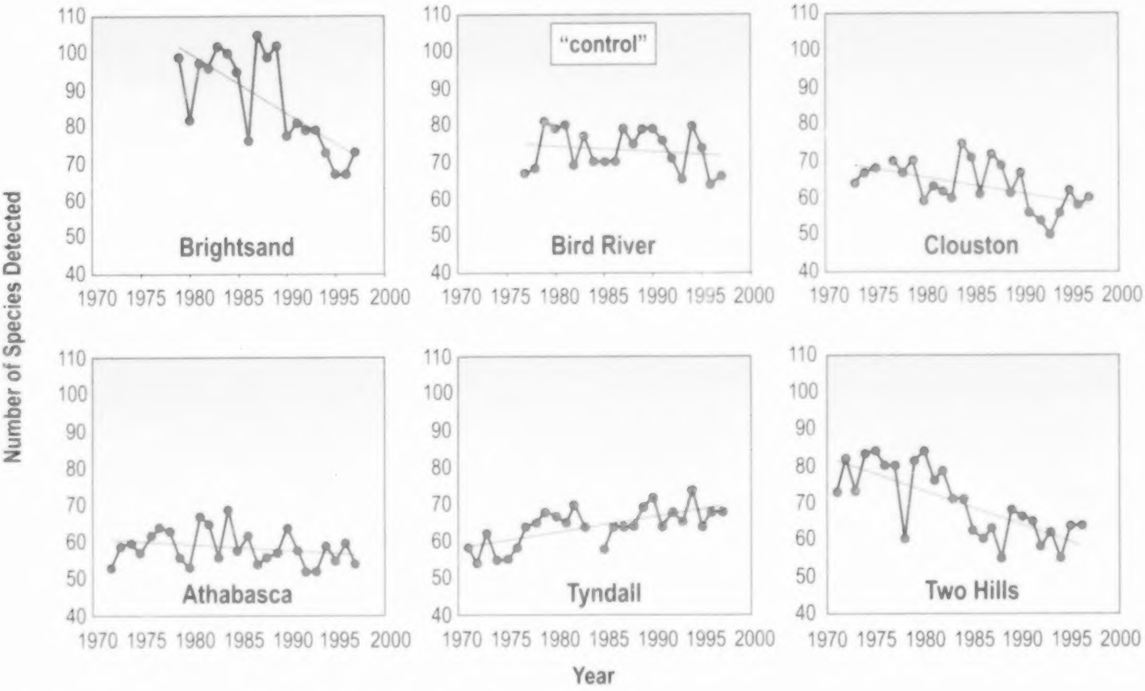


Figure 31. *Changes in time of bird diversity in the boreal plains.*

Spatial Variation in Bird Communities in Relation to Course-Scale Environmental Factors in Canadian Boreal Forest

K. Hobson and D. Kirk

The geographic coverage for monitoring birds is often biased and incomplete. Such programs as the Breeding Bird Survey offer the best data over time, but it is restricted to areas near towns and along roads where the volunteer surveyors live. We examined patterns of bird species composition and abundance relative to data on climate, soils, land features and forest types in the western boreal forest. To do this, we used models to answer the following questions:

- What are the main factors influencing bird populations in the boreal forest?
- How much variation in bird populations can be explained by such factors as climate, environment and location?
- What are the best predictive models for individual species?

Data were gathered from many researchers who have worked on bird populations in the boreal forest. These forests were pure (aspen) and mixed-wood (white spruce and aspen) stands. The data focus on birds in mature, relatively undisturbed forest. We used a variety of models to determine species composition, patterns and abundance.

In all, 168 species were counted in 1229 forest stands. The most important factors influencing patterns of abundance and composition were spatial location and tree species composition at the stand level. Bird species responded to regional (ecodistrict or ecoregion) forest cover. Our models could be used to predict changes in bird populations after human disturbances, including forest harvesting. As the forest changes, it is likely that some bird species will be affected positively and others negatively. But this depends on how forests are managed. Species that use old-growth mixed-wood forests may be negatively affected, especially if forests are replanted to single tree species. A broad-based monitoring system is needed for the boreal forest so that we can evaluate population trends as the climate changes and forest harvesting continues. Our database can be used to develop models to predict effects of these changes.

Discussion

WHAT HAS BEEN ACHIEVED DURING NREI?

The *Northern Rivers Ecosystem Initiative* (NREI) set out to answer questions and address recommendations from the *Northern River Basins Study* (NRBS). The NREI was a science-based effort to gain more information to help understand the impacts of human activities on aquatic ecosystems and their contributing watersheds. Many new policies, regulations and initiatives were put in place during the NREI study years. NREI research has, and will continue to, enhance government and industry initiatives. The discussion that follows describes what the NREI, governments, industry, and other stakeholders have achieved during the study years between 1998 and 2003. The following discussion is based on the key objectives set out for the NREI (*see Introduction, p. 2*).

North Arm Park, Great Slave Lake (Hurcomb, GNWT)

Pollution Prevention

As the northern basins are developed and human populations increase, the risk that more contaminants will enter the environment increases. Preventing pollution at its source is a fundamental way to protect the environment. Pollution prevention and continuous improvement in effluent quality remain important principles in guiding government regulatory activities.

Alberta uses its regulations and policies to promote reductions in toxic substances and to progress toward their eventual elimination. The Government of the Northwest Territories also has legislation and guidelines to prevent pollution. Programs include hazardous substances, waste management, air quality and environmental impact assessment and are delivered in conjunction with community Renewable Resource Officers. The Government of Canada has policies and regulations to reduce harmful chemicals in the environment. For example, the *Toxic Substances Management Policy* is designed to eliminate the release of pollutants that are toxic, bioaccumulate and persist in the environment. *Canada Wide Standards* are in place or being developed for a number of chemicals in industrial discharges that pose risks to the environment or people.

Although environmental regulations have proven to be an important mechanism for controlling pollution and protecting the environment, they are not static. Regulatory reviews and updates are a necessary and appropriate component of the governments' commitment to sustainable development.

For all major industries in Alberta, new projects and expansions have to go through Alberta Environment's Environmental Impact Assessment process. For these, the industry must outline ways they intend to protect the environment. In both Alberta and the Northwest Territories, industries monitor their effluents and receiving water as required in their approvals to operate.

Monitoring of effluents and emissions is a critical cornerstone for assessing the performance of municipal and pulp mill effluent treatment systems, and for assessing compliance. Alberta municipalities and industries will soon be able to report effluent discharge data electronically. Good quality assurance procedures are essential to make sure the data are reliable. The use of accredited laboratories for the analysis of environmental samples provides a standard for comparison between treatment systems and for reviewing long-term performance.

Cooperation among the governments of Canada, Alberta and the Northwest Territories has been very successful in protecting the environment. As well, industries and municipalities are developing new technologies to reduce pollutants in their effluents and air emissions. Industry has also contributed to partnerships that are committed to achieving ecosystem health and sustainability of development in the northern river basins.

Some of the major sources of pollutants in the northern basins are pulp mills, oil sands operations, municipal sewage treatment plants, and agriculture. These are discussed below.

Pulp Mills

People were particularly concerned about the effects of pulp mill effluents on the Peace and Athabasca rivers. In the past, several of the kraft pulp mills on these rivers were using elemental chlorine to bleach pulp. This produced a variety of contaminants in their effluents. Dioxins and furans are troublesome, because they are highly toxic and can bioaccumulate in plants and animals. As operating approvals came up for renewal during the 1990s, the kraft mills were asked to eliminate elemental chlorine in their process. Now, all of the mills that once used chlorine have changed to chlorine dioxide, which means that dioxins and furans are no longer produced. Amounts of all chlorinated organic compounds (as measured by AOX, which includes dioxins/furans) have declined in most pulp mill effluents over the past decade, while pulp production has increased.

All pulp mills are required to monitor the effects of their effluents on the environment. This includes end-of-pipe concentrations and fish and benthic invertebrates in the river. Results of this environmental effects monitoring can be used to assess the adequacy of regulations in protecting rivers. Alberta Environment will be conducting a detailed review of international standards for pulp mills. Future standards will be based on the adoption of the most appropriate pollution control technologies and continuous improvement. Pulp mill effluent contains high amounts of organic matter (which creates biochemical oxygen demand or BOD) and nutrients. In their approvals, Alberta Environment has requested that each pulp mill develop plans to reduce nutrients, BOD and toxicity in their effluents.

Oil Sands

Oil sands operations continue to expand. These operations have a major impact on the land, but so far there is little process water released to the environment, as it is contained in tailings ponds. The industry is looking for innovative ways to deal with this tailings water. The industrial demand for water will continue to increase. The Alberta government requires oil sands operators to reclaim disturbed land.

Air emissions from oil sands operations are a concern, however, because the substances released could harm soils, plants and animals. The operators of oil sands projects are required to report yearly on initiatives to reduce atmospheric emissions. As a result of these programs, emissions from these operations are being reduced substantially.

Sewage Effluent

Pollutants in sewage effluent include nutrients, bacteria, organic matter and sometimes ammonia, which can be toxic to fish. All municipalities in Alberta are required to treat their sewage before it is released to streams or rivers. As approvals for municipal sewage treatment plants come up for renewal, the municipality may be asked to upgrade their treatment process. This has already occurred for Grande Prairie and Jasper, and as a result of these upgrades, nutrients and other contaminants in effluents have been reduced. Fort McMurray's sewage treatment facility is scheduled to be upgraded within two-three years.

Agriculture

Another source of pollutants in the northern basins is agriculture. Crop and livestock production can both affect water quality. Many farmers and producers are increasing their focus on ways to protect water quality, reduce the use of pesticides and protect biodiversity. During the NREI study years, there were several initiatives to increase environmental and economic sustainability in agricultural production, including the *Agricultural Policy Framework* and the *Agricultural Operation Practices Act*. The latter includes standards for new and expanding confined feeding operations. Several Alberta government departments are jointly studying the effects of agricultural runoff on streams throughout Alberta, including five in the northern river basins.

Long-Range Transport Of Pollutants

Persistent organic contaminants and greenhouse gases that are transported by air currents are difficult to control, because actual sources may be unknown. Canada has shown a strong commitment to the reduction and elimination of these pollutants, and has signed several international agreements to deal with them. But little will be done until major polluting countries also sign.

Mercury is a contaminant of concern in the northern basins. It is toxic and can bioaccumulate in organisms. This means that even if small quantities are present in the environment, concentrations in fish can be high. Fish are traditional foods for many people, so human health could be affected. One NREI study[1] looked at atmospheric deposition of mercury, which is likely a source in the northern basins. The study found that the mercury levels recorded at Fort Chipewyan were lower than the average values from other Canadian sites. Industrial sources of mercury in major centres to the south are having only a small effect on levels of mercury in the Peace-Athabasca Delta. Specific sources of mercury in the area are unknown.

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[1] *Atmospheric Contribution to Mercury Loading in the Northern Aquatic Systems.* B.J. Wiens, M. Kellerhals and A.D. Pankratz

Lake Athabasca at Fort Chipewyan, Looking East [AENV]

Great Slave Lake and Slave River

Great Slave Lake is a major lake in the north, with an important commercial, recreational and traditional fishery. An environmental overview on the aquatic ecosystem of Great Slave Lake was completed in 2003[2]. It is based only on existing information. The report states that Great Slave Lake is a relatively pristine environment, but is vulnerable to stressors such as the Bennett Dam and other potential hydroelectric developments, over-fishing and shoreline development in sensitive areas.

The present status of fish populations in Great Slave Lake is largely unknown, although fishers report that whitefish populations are relatively stable. Lake trout populations have declined substantially in the West Arm, but it is believed that the populations in the East Arm are doing well.[3] The Great Slave Lake fishery provides an important economic opportunity for commercial and recreational purposes. But to sustain the fishery, additional controls on commercial harvest, net restrictions, and altered catch limits may be needed.[4]

Studies conducted during the NREI years have shown that contaminants derived from pulp mills and oil sands are either absent or barely detectable in Great Slave Lake. The presence of other contaminants, such as toxaphene, mercury and PCBs, point to the need to improve our understanding of their sources and ecological and human health implications.

During NREI, levels of contaminants were measured in sediments of the Slave River Delta.[5] These studies found that certain trace metals, PCBs and dioxins/furans exceeded Interim Sediment Quality Guidelines. It seems that the Delta is a sink for these contaminants, but it is not known when or where they came from.

Great Slave Lake [Hurcomb, GNWT]

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[2] *Evaluation of the Vulnerability of the Great Slave Lake Ecosystem*. D. Gregor *et al.*

[3] *Mackenzie River Basin State of the Aquatic Ecosystem Report*. Mackenzie River Basin Board.

[4] *Evaluation of the Vulnerability of the Great Slave Lake Ecosystem*. D. Gregor *et al.*

[5] *Sediment Bound Contaminants in a Remote Northern Delta*. D. Milburn and T. Prowse; *Observations on Sediment Chemistry of the Slave River Delta, Northwest Territories, Canada*. D. Milburn, M. Stone, M. English and T. Prowse.

Contaminants

Over the past decade, there was a concerted effort to reduce levels of contaminants in the environment, mainly through regulatory or technological initiatives. A major focus of both the NRBS and NREI was to gain more understanding of contaminants – where they come from and how they affect water, sediments and aquatic life, including fish. Some of the contaminants studied over the last decade come only from human activities, and several are toxic, persistent and can bioaccumulate in food chains. These chemicals are mostly chlorinated organic compounds, including dioxins and furans, PCBs, DDT and toxaphene. All of these chemicals were present to varying degrees in fish, particularly downstream of municipalities on the Athabasca and Wapiti rivers. Other chemicals of concern include hydrocarbons from oil sands, both from natural erosion of the oil sands in the Athabasca River basin and industrial oil sands operations.

Dioxins and Furans

Dioxins and furans are particularly troublesome, because they are highly toxic and persistent. Levels of dioxins and furans have declined in the northern rivers because kraft pulp mills have changed their pulping process to reduce or eliminate them. Even so, in one NREI study these chemicals were still found in suspended sediments immediately downstream of Hinton on the Athabasca River and Grande Prairie on the Wapiti River. The highest concentration of dioxin was from the Bear River, which flows into the Wapiti River. The type of dioxin present at this site suggests that it may have come from wood preservatives. Concentrations at other sites were much lower[6].

Levels of dioxins and furans have declined dramatically in most fish tissues since the early 1990s. However, the NREI found that dioxins and furans were present in burbot liver and at very low levels in the muscle of mountain whitefish. Levels of dioxins and furans were highest in burbot liver at the sites immediately downstream of the pulp mills at Hinton and Grande Prairie. The sources for these are not known, but it is possible that sediments are contaminated in the area from previous mill effluents.[7]

Polychlorinated Biphenyls

Polychlorinated biphenyls (PCBs) continue to be a concern in the northern rivers. Exposure to PCBs is via sediments, soil and animal or plant tissue, and therefore concentrations in water may not reflect the potential risk.

In the Athabasca and Wapiti rivers, NREI studies found that PCBs were dissolved in water, bound to suspended sediment particles and in the bottom sediments. The highest concentration in suspended sediments at all sites was found just downstream of Grande Prairie on the Wapiti River. In both suspended and bottom sediments of the Wapiti River, PCB concentrations were higher downstream of the pulp mill than upstream of it, and higher immediately downstream of Grande Prairie. The pulp mill location may be a source, possibly from a spill that occurred there in the late 1970s. Another source may be present along the Bear River, which flows through Grande Prairie.[6, 8]

In the Athabasca River basin, PCB levels in suspended and bottom sediments were higher downstream of Hinton than upstream, and higher in bottom sediments than those in the Wapiti River, although the highest concentrations were well below the CCME sediment guideline. The highest concentration in bottom sediments was found in a tributary in the Hinton area, which may indicate sources along the creek. There is no evidence to suggest that either the pulp mill or municipal effluents contain PCBs.[8]

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[6] *Contaminants in Water, and Suspended Particles from Specific Reaches of the Peace-Athabasca System.* M. Alaee et al.

[7] *Spatial and Temporal Trends of Organochlorine Contaminants in Fish from Alberta's Northern Rivers.* D. Muir and C. Fraikin

[8] *Investigations of PCBs in Bottom Sediments of the Bear-Wapiti-Smoky-Peace and Upper Athabasca River Systems, 1989-2000.* R. Hazewinkel and L. Noton

PCB levels in fish tissue are consistent with the findings for the sediments of the river. They have not declined in burbot liver from the Athabasca River immediately downstream of Hinton, or in the Wapiti River downstream of Grande Prairie, but they have declined at most other sites. But the types of PCBs present throughout the basins were similar. It is not known whether the sources are similar throughout the area or if fish are accumulating particular types while excreting other types.[9]

PCBs bioaccumulate in plants and animals, and therefore are present in highest concentrations in fish that eat other fish. Burbot will eat forage fish if they are available, but invertebrates if they are not. But one of the NREI studies showed that the diets of burbot were similar upstream and downstream of these municipalities, so it is likely that PCBs are trapped in downstream areas. PCBs may be retained in algae and invertebrates in the nutrient-rich areas downstream, which in turn may bioaccumulate in forage fish and therefore burbot.[10]

Specific sources of PCBs are unknown. It is possible that large quantities of PCBs from past releases remain in the bottom sediments, algae and invertebrates downstream of Hinton and Grande Prairie. Or, there may be old dump sites that are eroding, especially along tributaries that flow through these towns.

Pesticides

Pesticides were also investigated during NREI. DDT, toxaphene and other chlorinated organic pesticides were present in very low concentrations in fish tissue. DDT has not declined at many of the sites on the Peace and Athabasca river systems, nor in the Lesser Slave River, and levels have increased in sucker muscle samples from the Athabasca River. Neither DDT nor toxaphene has been used in this country for decades, so the sources are unknown.[9] Air currents from other parts of the globe likely transport some of these pesticides.

Oil Sands Hydrocarbons

The oil sands industry in northern Alberta has a major impact on the land, but so far has had little impact on the Athabasca River. Several constituents in oil sands are potentially toxic to aquatic organisms. Natural oil sands outcrops are present along the Athabasca River and its tributaries. The extent and nature of these hydrocarbons were investigated during NREI. There was a slight to moderate impact of these hydrocarbons on plants and animals in the river, but there was no evidence that industrial oil sands operations were having an effect, largely because wastewater is contained in tailings ponds.[11]

Another NREI study looked at the impact of oil sands tailings water on terrestrial vertebrates. Tree swallows were used as indicators of local contamination from tailings ponds. They are considered good indicators because they readily accept nest boxes, come back year after year and forage on aerial insects of aquatic and terrestrial origin within short distances from their nests. There were no differences in tree swallow reproductive success, nestling growth rate, and immune response between reclaimed wetland sites and reference sites. But increased activity of certain enzymes at the reclaimed sites suggested the presence of oil sands contaminants in the diet of nestlings at those sites. There was a strong potential for bioaccumulation of hydrocarbons in aquatic insects, which remain in the flying adult insects after they have emerged.[12]

Fish health was also studied in the oil sands area during NREI. Eventually, the tailings ponds at the oil sands plants may need to be discharged. One study looked at the present health of fish exposed to natural oil sands hydrocarbons and tailings pond water. Forage fish from downstream of the oil sands deposits had lower sex hormone levels and higher liver enzymes, both of which indicate that these fish were exposed to foreign chemicals. As well, larval fish exposed to refinery wastewater and natural hydrocarbons showed deformities and mortality.[13] In addition to the NREI studies discussed here, considerable monitoring work is being conducted through the *Regional Aquatic Monitoring Program*, as well as scientific research throughout the oil sands area.

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[9] *Spatial and Temporal Trends of Organochlorine Contaminants in Fish from Alberta's Northern Rivers*. D. Muir and C. Fraikin

[10] *Contaminant Biomagnification in Specific Reaches of the Peace-Athabasca River Ecoystem - Study Highlights*. M.S. Evans and D. Muir

[11] *Assessment of Natural and Anthropogenic Impacts of Oil Sands Contaminants within the Northern River Basins*. R.B. Brua, et al.

[12] *The Ecological Viability of Constructed Wetlands at SUNCOR: Population and Health- related Considerations in Birds and Amphibians*. M. Wayland and J. Smits

Although the oil sands industry is not affecting the Athabasca River now, it may in the future. We know that natural hydrocarbons enter the river by erosion of oil sands deposits, but little is known about how plants and animals take up the hydrocarbons or what the long-term effects might be.

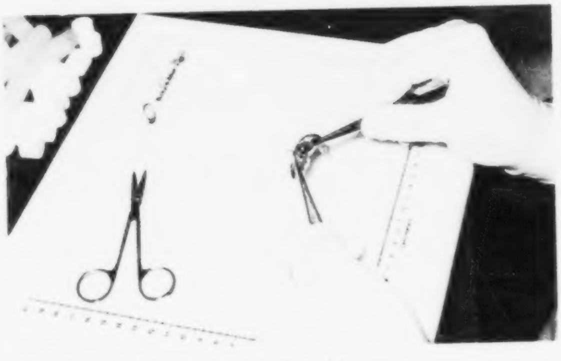
Natural Seepage of Oil Along a Tributary of the Athabasca River *[Environment Canada]*

Endocrine Disrupting Substances

Research during NRBS suggested that there was potential for reproductive problems in fish because of certain substances in pulp mill effluents. Pulp mill effluents are highly complex. As wood is broken down into pulp, a variety of compounds are produced. Some of these mimic natural hormones in fish, which could lead to reproductive problems and declining fish populations. This is called endocrine disruption.

One NREI study looked at pulp mill effluents to try to identify substances that could cause endocrine disruption. Effluent samples were brought into the laboratory and tested for these compounds. The tests confirmed that these substances were present in effluents, but there was no relationship between the type of mill process or the treatment of the effluent before discharge.[14]

Another NREI study looked at endocrine disruption in wild fish at several sites above and below three pulp mill effluents on the Athabasca and Wapiti rivers. The fish collected downstream of effluents showed some reproductive impairment compared with those from upstream, although this was also true of fish caught below the municipal effluents. But nutrient enrichment below both of these effluents may mask some endocrine responses. For example, fish that are in better condition because more food is available may offset depressed reproductive function due to endocrine disruptors in their environment. In general, the researchers concluded that endocrine disruption in fish in these rivers was minimal.[15]



Fish Dissection *[Environment Canada]*

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[13] *Fish Health Effects from Wastewater Discharges and Naturally Occurring Compounds in the Athabasca River System.* J. Parrott *et al.*

[14] *Characterizations of EDCs at Pulp Mill Sites in the Northern Rivers Basin.* L.M. Hewitt, M.E. McMaster, M. Kohli, A. Pryce, J.L. Parrott, G.R. Tetreault and G.J. Van Der Kraak

[15] *Detailed Endocrine Assessments in Wild Fish within the Northern Rivers Basin.* M. McMaster, M. Hewitt, G. Tetreault, J. Parrott, G. Van Der Kraak, C. Portt and N. Denslow

Fish Abnormalities

Northern residents were concerned about abnormalities in fish they caught, especially downstream of pulp mills. The most common abnormalities include fin erosion, gill discoloration, tumours and external parasites. The *Environmental Effects Monitoring* (Cycle 2) program conducted by the pulp mills during the NREI study years showed that fish abnormalities were slightly higher in some sections of the Athabasca River, especially downstream of pulp mills.[16]

Alberta Sustainable Resource Development reviewed the protocols used by various jurisdictions and institutions within Canada for collecting, handling and reporting information on fish tissue contaminants and abnormalities. Alberta will be developing a protocol for recording, reporting and handling information on the incidence of fish abnormalities as part of its Fisheries Management Information system. It is not fully known what fish abnormalities in the northern rivers mean to fish health and populations, nor are the causes known.

Drawing Blood from Fish (Env. Canada)

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[16] *Summary of Cycle 2 Environmental Effects Monitoring Results from Pulp and Paper Mills in the Northern River Basins.* J. Ferrone and S. Blenkinsopp.

Human Health/Drinking Water

A major concern for residents of the northern basins was about human health – was it safe to drink the water and eat fish from northern rivers. The outbreaks of disease from improperly treated drinking water in several Canadian cities have resulted in much more attention on drinking water treatment across the country. Fish are a significant part of traditional diets, and therefore it is important that they are safe to eat. The NRBS found that fish were contaminated with low concentrations of several contaminants, including mercury, PCBs and dioxins and furans. The NREI conducted follow-up studies on contaminants in tissues of several species of fish in the northern river basins.

Drinking Water

Municipalities provide treated drinking water to its citizens. Several provincial and federal government agencies have jurisdiction over drinking water quality, and all of them promote upgrading of water treatment facilities. This includes new technology, improved testing and more training for operators. For example, small communities often have difficulty in hiring trained personnel to make sure that water treatment facilities are operated properly. But, the governments are committed to improving education and training for operators. Many First Nations communities, in particular, have taken an active role in ensuring that their operators are trained and drinking water is tested. Education and awareness programs are also promoting a broader perspective by focussing on drinking water quality from the source water to the tap.

Several initiatives were put in place during the NREI study years to make sure water from municipalities is safe to drink. Alberta Environment, in collaboration with Alberta Health and Wellness, is reviewing all approved waterworks systems to make sure they can continue to supply safe drinking water well into the future. The project, which is funded by Alberta's *Water for Life*, will identify long-term solutions and their costs. The Alberta government has developed a procedure to deal with bacteriological sample results that exceed drinking water guidelines. The protocol involves the owners and operators of systems, who are ultimately responsible for water quality. In May of 2003, the federal government announced a new initiative to deal with the safety of drinking water in First Nations communities and released the "*Water: Source of Life*" information kit. This work by Health Canada and Indian and Northern Affairs Canada has culminated in the development of a *First Nations Water Management Strategy* to be implemented over 5 years.

In the Northwest Territories, government departments are working together, and with other agencies, to define actions to implement *Managing Drinking Water in the NWT - A Preventative Framework and Strategy*. Some of the actions under way include training, public access to data, watershed management, and routine reviews and upgrades of water treatment plants.

Fish

Many of the harmful contaminants in the northern rivers bioaccumulate through food chains, which means that fish that eat other fish will have higher levels than fish that eat invertebrates. As well, large fish likely have higher contaminant levels than small ones. During NRBS, it was found that fish tissues had low levels of several chlorinated organic compounds and mercury.

Fish consumption advisories have been set up to protect people from harmful effects of contaminants in fish they eat. Because mercury and dioxins/furans are very toxic, the advisories pertain to these substances. Mercury has natural sources along the northern rivers and in several lakes, while dioxins/furans came mostly from pulp mill effluents. Walleye from the Athabasca River may have elevated concentrations of mercury, and therefore women of child-bearing age and young children should not eat these fish. Other people should eat no more than one meal per week. Other fish may have very low concentrations, but are considered safe to eat.

One of the NREI studies looked at dioxins and furans in fish tissue over time. Since the pulp mills changed their bleaching process, dioxins and furans in fish tissue have declined, and fish consumption advisories have been revised accordingly. The advisory is now less restrictive for dioxins and furans, although people should not eat burbot liver. The liver and other internal organs have more fat, and so they have the highest concentrations of toxic compounds. Advisories are updated periodically, so consumers should check the most up to date issue of the *Alberta Guide to Sportfishing Regulations* to make sure fish in their area are safe to eat.

Fish for Sample Collection (Env. Canada)

PCB concentrations in muscle of mountain whitefish, bull trout and longnose sucker from the Athabasca river system are relatively low and similar to observations in the same or related species in northern Canada. Little is known about the long-term effects of PCBs on human health, although exposure to high levels can cause a variety of health problems, including a greater risk of cancer.

In response to the concerns identified by First Nations people, the Alberta Treaty 8 Health Authority began a partnership with the eight First Nations and Health Canada to develop fish consumption guidelines for people relying on traditional foods. The first stage of the work involved an examination of food use within eight communities in Northern Alberta. Results of this work will set the stage for developing fish consumption guidelines that reflected uses made by First Nations people and others reliant on traditional food. The second stage included the collection and analysis of fish samples from waters used by the eight communities for traditional food. This work includes a partnership between Alberta Health and Wellness and Alberta Sustainable Resource Development.

Hydrology And Climate

It has long been recognized that flows in the Peace and Athabasca rivers are important to the ecological integrity of the Peace-Athabasca and Slave River deltas. Much of the PAD experienced a prolonged drying period from 1975 to 1996. After flooding in 1996 and 1997, the PAD started to dry out again. There is also some concern that the Slave River delta has been subject to drying over the past few decades. Many people believe that the W.A.C. Bennett Dam on the Peace River is the main cause of the drying that has occurred in the deltas. NRBS studies found that the dam influenced flows in the Peace River. But climate change is also having a great effect on the deltas as well.

Traditional knowledge suggests that the temperature is increasing, weather is becoming more variable, and water levels in lakes, rivers and the deltas are declining. This is supported by scientific evidence. Over the past 30 years, average temperatures have increased. Recent decades have been wetter in summer and drier in winter.

Even at the end of the NRBS, the impact of climate change was just being recognized as a major environmental issue, and a few recommendations suggested it should be looked at as context for other issues. Based on the results of the NRBS studies and a flooding event that occurred in 1996, there was clearly a need to get a better understanding of how the climate was influencing the hydrology of the deltas. Several NREI studies provided more information on the interaction of the Bennett Dam and climate change on the deltas, and tools were developed or improved to be able to predict future events in the area.

One of the NREI studies used remote sensing techniques to map the extent of flooding and vegetation within the Peace-Athabasca Delta. The delta was subjected to major overland flooding in the spring and summer of 1996 and in the spring of 1997. During the following years, the delta went through a drying trend with receding water levels. The flood duration maps show that the rivers, lakes and many of the wetland basins became isolated as the floodwater receded. The remote sensing maps were very useful in discovering delta-wide relationships. Satellite remote sensing affords the only reliable means of assessing flood extent in this region.[17]

Two other studies looked at the hydrology and climate of the Peace-Athabasca delta. For one of these, water balance models were set up to predict how long it takes the perched basins in the delta to dry out under present conditions and when the climate is warmer. These basins lose water through evaporation and regain water when the rivers flood. Computer modelling suggested that the basins will dry out even more rapidly than at present as the climate changes. The Dam also tends to reduce flood peaks because upstream flows are captured and under future climates this may be exacerbated.[18, 19]

Other models were used to route flows in the Peace and Athabasca basins down to the Peace-Athabasca Delta and within the delta. Under future climate conditions, models indicate a shift in the timing of the peak runoff and a potential increase in total annual flow reaching the delta. Inflows to Williston Reservoir likely won't change but there could be a shift in the timing of inflow, with higher inputs during the winter and lower inputs during the summer. Models also indicated that water levels in the major lakes could be affected with earlier peak levels and potentially lower water levels during the open-water period although there is variability between various climate models.[19]

Much less is known about the Slave River Delta. Climate change and regulation also affect this delta, and parts are also drying. Effects of the Dam are less because the delta is further downstream, however. One of the NREI studies assessed the impact of changing levels in Great Slave Lake on the delta. Most of the inflows to the lake come from the Peace and Athabasca rivers to the south. The Dam has altered the annual cycle of lake levels. Because the Slave River Delta is very flat, changes in the timing of peak water levels in the lake could affect the ecology of the delta.[18]

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[17] *Monitoring Delta Ecosystem Response to Water-Level Restoration*. A. Pietroniro and J. Toyra

[18] *Hydro-climatic Impacts Affecting the Peace-Athabasca-Slave Catchments and Deltas*. T.D. Prowse, *et al.*

[19] *Modelling Climate Change Impacts on Water Availability in the Peace-Athabasca Catchment and Delta*. A. Pietroniro, *et al.*

Although these NREI studies have provided new insights on the influence of climate on the Peace-Athabasca and Slave deltas, they have also created new questions. In particular, what is the impact on the ecology of the deltas under a warmer climate? There will be a need to consider if and how flow regulation could be used to protect the delta environment. The tools and techniques developed during NREI can be used to assist in developing basin management plans for these globally important areas.

Hydroelectric Power Grid, W.A.C. Bennett Dam (AENV)

Integrated Environmental Monitoring

One of the NRBS recommendations was to create a group to oversee monitoring and research activities in the Mackenzie River Basin. This would standardize monitoring techniques and improve overall knowledge. In 1997, the governments of Canada, British Columbia, Alberta, Saskatchewan, the Northwest Territories and Yukon signed the *Mackenzie River Basin Transboundary Waters Master Agreement*. The Agreement commits the governments to maintain the ecological integrity of aquatic ecosystems in the basin while allowing sustainable development and equitable use of the water. The *Mackenzie River Basin Board* was set up to implement it. The Board's vision is "a healthy and diverse aquatic ecosystem for the benefit of present and future generations."

A technical committee was formed by the Board to oversee monitoring activities throughout the Mackenzie River Basin. The committee coordinates information management within the basin, assesses existing data, reviews issues of concern within the basin, identifies data gaps and develops monitoring guidelines and programs.

Environmental Indicators

Environmental indicators are physical, chemical or biological features that can be monitored and used to measure changes in the environment, particularly over the long term. During NRBS, seven indicators were established for the ecological integrity of the Peace-Athabasca Delta. The indicators included climate, water quality, water levels, the abundance of a single invertebrate species and fish populations.

Then, during 2000-2002, NREI researchers evaluated the indicators to assess changes in the Delta. Most of the ecosystem goals were being met, including those for fish populations, but climate was not. The annual temperature in the Delta has increased, and precipitation patterns are different now. The invertebrate, a clam shrimp, was not found in samples in 2000 and 2002. The researchers did not know the reason for this.[20]

In another NREI study, four biological ecosystem indicators were proposed for the Slave River Delta: plant communities, goldeye populations and condition, shorebird reproductive success and muskrat populations. Additional information is needed to test the proposed measurement for each indicator.[21]

The Mackenzie River Basin Board published the *Mackenzie River Basin State of the Aquatic Ecosystem* report in 2004. It also used indicators, as well as traditional knowledge reporting, to assess whether the Board's water management goals are being met. For the Athabasca River Basin, many of the indicators were rated as Favorable, but there were some with Mixed Signals. But traditional knowledge of human health and safety received an Unfavorable rating because native people perceived a health risk to using the water. For the Peace River Basin, traditional knowledge assessments reported unfavorable on all goals. As well, several other indicators showed Mixed Signals. For the Slave River, traditional knowledge assessments were all rated as Unfavorable or Deteriorating. River flows and timing of spring flows received Mixed Signals, indicating that more information is needed.[22]

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[20] *State of the Aquatic Environment - Peace-Athabasca Delta - 2002. D. Donald, et al.*

[21] *Ecosystem Maintenance Indicators for the Slave River Delta, Northwest Territories, Canada. D. Milburn, et al.*

Issues Management Through Partnerships

Although regulation, monitoring and assessment of air and water quality are generally the jurisdiction of governments, many organizations have formed in the past few years to help manage the environment. Most of these organizations are based in specific areas of the north.

For example, many people are concerned about the impact of the expanding oil sands industry on the environment. The *Regional Sustainable Development Strategy* (RSDS) was set up to manage cumulative environmental effects of multiple developments in the Athabasca oil sands area. The group is working on several themes, including sustainable ecosystems, impacts of air emissions and water quality and quantity. The stakeholder group for RSDS, the *Cumulative Effects Management Association*, will deliver management recommendations on environmental capacity guidelines and management systems. The *Regional Aquatic Monitoring Program* is a joint effort of industry, aboriginal groups and government agencies. Its purpose is to monitor the effects of oil sands activities on the aquatic environment. The data collected will be used to determine cumulative effects and to verify predictions in the environmental impact assessments for the companies. The *Wood Buffalo Environmental Association* monitors air quality and effects of air pollutants in the oil sands area.

Good air quality is important to northerners. Alberta's *Clean Air Strategic Alliance* was formed to make sure that air emissions are having no harmful effects on people or the environment. The Alliance and the provincial government monitor air quality in regions where stakeholders have concerns about specific issues.

Cumulative Effects Assessment

Cumulative environmental effects are the changes to the environment from a human activity in combination with other past, present and future activities. Cumulative Effects Assessment is a process to assess how all stressors are impacting on an aquatic system and if the system can tolerate new development.

At present, there are two approaches to cumulative effects assessment. Project-based assessment focuses on one development and its impact on the environment. This assessment focuses on a local scale – but impacts that may seem unimportant at this scale may be very important at larger scales, such as the whole river. Regional-based assessments measure the response of the aquatic environment to stressors from multiple developments. The condition of the environment is measured first, and then if impacts exist, the stressors causing the impact are then identified. But the limitation of this approach is that the stressor is identified after the impact has occurred.

An NREI study developed a cumulative effects assessment framework in which the strengths of both approaches are integrated. The framework depends on a regional aquatic information system where many different agencies input data, which is then integrated and evaluated on an on-going basis to identify areas of poor to good aquatic health. If new developments are proposed, the developers and regulators use this information to see if the environment could tolerate new development.[23]

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[22] *Mackenzie River Basin State of the Aquatic Ecosystem.* Mackenzie River Basin Board.

[23] *Development of a Cumulative Effects Assessment Framework for Aquatic Ecosystems: the Northern Rivers Ecosystem Initiative Demonstration Project.* M. Dube *et al.*

Nutrients and Dissolved Oxygen

Dissolved oxygen (DO) is one of the most fundamental substances in water. If DO levels become too low, many types of fish and other animals could die. Nutrient levels play a role, because when nutrients are abundant, plants grow rapidly. Then, in winter this biomass of plant material decomposes and uses up DO. As well, the decay of organic material from sewage and pulp mill effluent consumes oxygen. Several NRBS recommendations were related to dissolved oxygen and nutrients, and several NREI studies addressed these.

The dissolved oxygen guideline (6.5 mg/L) adopted by Alberta and other jurisdictions, including CCME, assumes that there would be no more than 3 mg/L difference between dissolved oxygen levels in the river bottom and in the water above it. Thus, it is assumed that fish eggs and benthic organisms would be protected if the water column dissolved oxygen remains above the guideline level. But NREI research showed that there was little relationship between dissolved oxygen levels in the pore water and that in the water above. These findings make the usefulness of the dissolved oxygen guideline uncertain. However, we don't know whether low porewater DO really affects fish and their food. It is possible that enough eggs are produced that fish populations wouldn't be harmed or that fish preferentially select locations with good porewater DO. As well, the Alberta guideline for water column dissolved oxygen is higher during critical time periods, which should help protect fish eggs and benthic invertebrates in the bottom sediments of rivers. Future DO guidelines may need to be based on site-specific conditions (e.g., bottom type, location of spawning areas, flow and effluent inputs).[24]

Nutrients are discharged by municipalities and pulp mills, as well as occurring naturally. They stimulate the growth of plants, which in turn increases the productivity of the river environment. This could mean more and bigger fish. But when nutrient inputs are too high, plant growth can become excessive and low dissolved oxygen levels could result. This is part of the reason AENV monitors winter DO on the Athabasca River system, and has undertaken assessments of benthic invertebrate community response to the winter DO conditions. A management committee has been established with the pulp mill industry and other stakeholders to begin to address these issues on the upper Athabasca River.

Algal Growth on Rocks from the Athabasca River near Whitecourt (AENV)

One of the NREI studies looked at the relationship between nutrient levels and plant growth in the Athabasca and Wapiti rivers. Levels of nitrogen and phosphorus increased in a downstream direction, and the amount of algae on rocks and the bottom also increased. Phosphorus was the main nutrient that controlled algal growth in the upper portions of the Athabasca River, which means that if more phosphorus enters the river, algal growth could increase. Both nitrogen and phosphorus controlled algal growth in the Wapiti River. Nutrient guidelines were proposed for each area of these rivers.[25]

Another NREI study used on-shore tanks into which Wapiti River water and various proportions of municipal and pulp mill effluent were added to study the effects of nutrient enrichment. In this way, the effects of the two effluents could be studied separately and in combination. Several experiments were run with fish, algae and benthic invertebrates. The results indicated that productivity increased due to the combined effects of nutrients – nitrogen from the municipal effluent and phosphorus from the pulp mill effluent. Juvenile fish had the poorest condition when the amount of pulp mill effluent was greatest, and there was some evidence of reproductive problems in adults. But at lower concentrations of effluent, juvenile condition was better than those in control tanks. As well, municipal effluent slightly altered male gonad size and hormone levels. These results are consistent with those of other NREI studies. In general, however, these effluents do not *strongly* affect plants and animals in the river.[26]

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[24] *Dissolved Oxygen Relationships of Water Column and Pore Water Habitat: Implications for Guideline Improvements* J. Culp *et al.*

[25] *Setting Nutrient Guidelines for the Northern Rivers of Alberta* P. Chambers and M. Guy

[26] *Mesocosm Assessment of Pulp Mill and Municipal Sewage Effluent Effects on Benthic Food Webs and Longnose Dace (Rhinichthys cataractae) of the Wapiti River, AB.* J. Culp *et al.*

Integrated Planning of Land and Water Use

Activities on the land can affect streams, rivers and lakes. Watershed management plans are key tools to help protect the land, wildlife, rivers and lakes. Under NREI, models and assessment tools were developed or refined to help resource managers assess, plan and manage watersheds and their rivers. As well, new government policies and regulations will help reduce human impacts on the land and in the water.

Increasingly, governments are using an integrated approach for managing water and the environment. How we manage or use one resource affects the management or use of other resources in an area. Managing each use or resource by itself is less effective than managing all of them in an integrated way.

One NREI study modelled the runoff contribution from a variety of land uses. The model can be used to evaluate the impacts of land clearing and conversion, wildfires and revegetation on water supplies. Once the model is set up for a particular area, it can be used to assess improvements in land management practices or predict in-stream flow needs for aquatic life. The model showed that changing the proportions of vegetation in a watershed could affect the amount of runoff and therefore the amount of flow in streams.[27]

Alberta's *Water Act* addresses multiple uses for water while promoting the wise use of the resource. It states that water management is a shared responsibility of all Albertans. A framework was developed so that water management plans could be set up for watersheds in the province. The plans will be based on principles of integrated resource management, which considers environmental, social and economic issues. These management plans should provide long-term protection for northern rivers. Within the framework is a strategy to protect aquatic environments. It reflects the province's commitment to maintain or restore the aquatic environment.

Alberta is facing pressures on its water resources. Population growth, drought and agricultural and industrial development put stress on the province's water systems. *Water for Life: Alberta's Strategy for Sustainability* envisions Alberta's governments, stakeholders and the public cooperating in a network of community, basin and provincial partnerships – combining knowledge and resources to manage Alberta's water in an efficient and effective manner. This new strategy addresses water management concerns for the future. It is the most comprehensive of its kind in Canada.

A watershed approach is proposed for the new strategy. This is a focus of efforts within a watershed, taking into consideration both groundwater and surface water. This approach recognizes and plans for the interaction of land, water, plants, animals and people. Focussing efforts at the watershed level gives local communities within that watershed a comprehensive understanding of local management needs and encourages locally led management decisions.In March 2003, draft recommendations were released for a *Northern East Slopes Strategy*. This area includes the upper watersheds of the Athabasca and Smoky rivers. This is the first regional strategy of its kind in Alberta. Themes for the Strategy include appropriate land use, sustainable resource development, and protection of native plants, wildlife, air, water and soil.

During the NREI years, the Alberta government released the draft terms of reference for a water management plan for Lesser Slave Lake and River Basin. The purpose of the plan is to help Alberta Environment make water resource decisions. Development of the plan will be a partnership between the government and numerous stakeholder groups. One of the goals is to protect the aquatic environment by managing activities that affect water quality, water quantity, habitat and aquatic species.

A management plan is needed for the Wapiti River. The new scientific information obtained during NREI, coupled with effluent improvements, water allocation and instream flow needs provides a solid basis upon which a future watershed management plan can be developed.

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[27] *Impact of Land Use on Water Balance and River Discharge.* R. Granger *et al.*

During NRBS, a series of technical studies were completed to determine the hydrology of the Peace-Athabasca Delta and how the Bennett Dam affected it. Then, the governments involved began discussions to develop an ecosystem management plan for the Delta. A draft plan was prepared in 2000 and presented to the main stakeholders. New information collected during NREI and the updated models should help with future planning for this important area.

A long-term commitment to water quality management is the new water quality performance measure reported annually by Alberta Environment. The performance measure is a water quality index calculated at key river locations throughout the province. It is based on four groups of variables: bacteria, nutrients, metals and pesticides. Eventually, other chemical groups, such as AOX and toxic contaminants, will be included.

Farmland near Falher, Alberta, in the Peace River Basin (AENV)

Lesser Slave Lake (AENV)

Wildlife

A major challenge now and in the future is to preserve biodiversity. Human alteration of habitat is the single greatest threat to biodiversity around the world. One area that is home to a great variety of wildlife is the Peace-Athabasca Delta. Another important habitat is the boreal forest – much of the northern basins are covered in forest, which is essential to billions of birds.

The Peace-Athabasca Delta

The viability of the perched basins in the Peace-Athabasca Delta depends on periodic flooding. In spring of 1996, when there was a large snowmelt runoff, BC Hydro released additional flow from the Dam and the Delta flooded. Then in summer of the same year, a structural problem at the Dam required the reservoir to be lowered, and a large volume of water was released. This coupled with high precipitation caused flow reversals into the delta. This flow reversal from the Peace River along with high flows on the Athabasca River resulted in additional flooding within the delta. Since then, the amounts of open water and flooded vegetation in the Delta have declined.

After the 1996 flood, waterfowl use of the Delta was very high. By 2001, waterfowl populations had declined to pre-flood levels. Flood events are crucial to waterfowl use of the Delta. Although all water bodies are used for brood rearing, some are more important than others.[28]

Migrating shorebirds also use the Delta. As the perched basins dry after flooding, mudflats are exposed. This provides excellent habitat for shorebird use. Fluctuating water levels are doubly beneficial – as they decline, large areas of mudflats are exposed, but as they flood, they kill off encroaching vegetation. Habitat conditions along the migration route may influence the number of stops required by these birds and dictate whether the delta is used or not.[29]

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[28] *Peace-Athabasca Delta Waterbird Inventory Program 1998-2001 Final Report.* E. Butterworth *et al.*

[29] *An Investigation of Migrant Shorebird Use of the Peace-Athabasca Delta, Alberta in 1999.* G. Beyersbergen.

The Boreal Forest

Commercial forest harvesting in the boreal forest has a major impact on biodiversity, especially of birds. Several NREI studies found that the diversity and abundance of birds in the boreal forest were highest in mature stands of timber. It is critical to make sure that forest stands are managed in an environmentally sustainable way.[30]

Seismic exploration can also have a major impact on the boreal forest. Impacts include loss of forest habitat and fragmentation of the forest, increased access to off-road vehicles and destruction of aquatic habitat. Since late 1996, companies exploring for gas and oil in the green zone are required to use low-impact seismic lines, which greatly reduces the impact. In sensitive areas, only minimal-impact seismic exploration is allowed.

Several organizations were set up to manage fish and wildlife issues. The *Alberta Conservation Association* uses funds from a variety of conservationists, including hunters and anglers, to inform the public, collect data and facilitate a variety of projects to conserve Alberta's wildlife, fish and their habitat. *Ducks Unlimited* is an organization set up to protect waterfowl populations by conserving, restoring and managing wetlands. The mandate of Environment Canada's *Western Boreal Conservation Initiative* is to conserve and protect western boreal forest ecosystems and their biodiversity.

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[30] *Large-Scale Conversion of Forest to Agriculture in the Boreal Plains of Saskatchewan*, K. Hobson et al.; *Spatial Variation in Bird Communities in Relation to Course-Scale Environmental Factors in Canadian Boreal Forest*, K. Hobson and D. Kirk; *Ecological Basis for Stand Management: A Synthesis of Ecological Responses to Wildfire and Harvesting*, S. Song, ed.

Little Smoky River near Valleyview (AENV)

Seismic Lines in Northern Alberta Muskeg (AENV)

LEGACY OF THE NORTHERN RIVERS ECOSYSTEM INITATIVE

The governments of Canada, Alberta and the Northwest Territories began the *Northern Rivers Ecosystem Initiative* to respond to recommendations from the *Northern River Basins Study*. The completion of the final reports from the NREI, in one sense, brings to a conclusion the NRBS, which was initiated more than ten years ago. But in a broader sense, these two studies will continue through the legacy of knowledge and awareness they have generated over the past decade.

We now know much more about the environment and the impact of human activities in the basin. This awareness has prompted governments to strengthen and augment policies and regulations that protect the health of ecosystems, yet allow for sustainable development. We know, for example, that changes in technology in the pulp and paper industry have reduced amounts of contaminants entering the northern rivers. More stringent regulations for municipal sewage treatment are starting to reduce levels of nutrients in their effluents.

Contaminants are still present in fish and sediments, in spite of these new regulations and technologies. In particular, levels of PCBs have not declined in the environment. The precise sources of these substances are not fully understood and therefore they would be difficult to clean up. At present, natural and industrial sources of hydrocarbons from oil sands are having only a minor impact on the Athabasca River. But NREI studies have suggested that tailings pond water could harm aquatic life and other animals that may use them. At present no wastewater is discharged directly to the river, but an accidental release could have a major effect. Contaminants are also transported by air currents from other parts of the world and deposited in the northern basins. Although little can be done about this locally, Canada will continue to promote reduction of these pollutants internationally and to insist on reductions within this country.

Protection of human health will continue to be one of the most important considerations for the northern basins. NREI studies have shown that dioxins and furans have declined in fish tissues and therefore certain fish consumption advisories are less restrictive. Mercury is still a concern in some parts of the northern basins, however. A new emphasis on drinking water treatment throughout the country will help ensure that water is safe to drink.

The NRBS and NREI have promoted integrated resource management and the watershed approach to planning. New monitoring and assessment tools were developed, which will contribute to basin management and stewardship. Partnerships with industry, governments, First Nations and environmental groups will provide ongoing mechanisms for maintaining awareness and managing environmental problems. Industrial, government and citizen monitoring programs throughout the northern basins will continue to evaluate impacts on the environment.

Another challenge is protecting biodiversity on land and in water. New environmental organizations, policies and initiatives have been put in place during the NREI study years to address this issue. The boreal forest covers much of the NREI study area. Increasingly, forest companies are harvesting in a way that promotes multiple uses of the forest, including protection of birds and other wildlife that live there.

The Mackenzie River Basin Board will cooperate with all jurisdictions to ensure that ecological integrity is preserved throughout the Mackenzie Basin, and will oversee monitoring, assess data and provide information to people in the basins. The Board's state of the environment reports, which will be prepared every five years, will determine how the environment is doing and help identify any new problems.

Alberta is taking a proactive approach to managing the environment. The new Alberta water strategy, called *Water for Life*, will address water management concerns for the future. Its three goals include maintaining a safe, secure drinking water supply; healthy aquatic ecosystems; and reliable water supplies for a sustainable economy.

Similarly, the Government of the Northwest Territories also recognizes the need to protect rivers, lakes and drinking water. It is an active partner with the federal and western provincial governments to make sure that water flowing into the Northwest Territories is conserved and protected.

All of these new initiatives and knowledge will need to be considered in light of a changing climate. Global warming is the greatest threat to the northern environment. We don't know precisely how climate change will affect river flows, lake levels, concentrations of contaminants and fish and wildlife habitat. Climate change should be considered as context for all new developments and management plans.

Although the NRBS and NREI are now finished, we now have a priceless legacy of knowledge and awareness. And it is this knowledge and awareness, manifest in the peoples of the northern river basins, which will guide the environmental future of the north and help protect the traditional way of life.

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http://www3.gov.ab.ca/env/WATER/Index.cfm
Alberta Environment water home page.

http://www.mb.ec.gc.ca/nature/ecosystems/nrei-iern/index.en.html
Northern Rivers Ecosystem Initiative home page.

http://www.mb.ec.gc.ca/water/index.en.html
Environment Canada water home page.

Climate Change

http://www.ipcc.ch/
The Intergovernmental Panel on Climate Change (IPCC) has been established by WMO and UNEP to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation. It is open to all Members of the UN and of WMO.

http://unfccc.int/2860.php
Over a decade ago, most countries joined an international treaty – the United Nations Framework Convention on Climate Change – to begin to consider what can be done to reduce global warming and to cope with whatever temperature increases are inevitable. In 1997 governments agreed to an addition to the treaty, called the Kyoto Protocol, which has more powerful (and legally binding) measures.

http://www3.gov.ab.ca/env/climate/index.html
In October 2002, the Government of Alberta released Albertans & Climate Change: Taking Action, Canada's first government action plan to address climate change and reduce greenhouse gas emissions.

Legislation and Regulatory

http://www.ccme.ca/initiatives/standards.html
Canadian Council of Ministers of the Environment is the major intergovernmental forum in Canada for discussion and joint action on environmental issues of national and international concern.

http://laws.justice.gc.ca/en/C-15.31/
Canadian Environmental Protection Act, 1999. Document on-line and available as a pdf file

http://laws.justice.gc.ca/en/F-14/
Fisheries Act. Document on-line and available as a pdf file.

http://www.naaec.gc.ca/eng/index_e.htm
The North American Agreement on Environmental Cooperation (NAAEC) is the environmental side agreement to the NAFTA. The NAAEC was signed by Canada, Mexico and the United States and came into force January 1, 1994. The Agreement creates a framework to better conserve, protect and enhance the North American environment through cooperation and effective enforcement of environmental laws.

http://www3.gov.ab.ca/env/protenf/approvals/factsheets/enhanact.html
Since its creation in 1971, Alberta Environment has been responsible for a broad body of environmental legislation. Following extensive public consultation, the Environmental Protection and Enhancement Act (EPEA) became law on June 26, 1992, coming into force on September 1, 1993. It created this new framework in a single act that takes an integrated approach to the protection of air, land and water. The Act strengthens and clarifies Alberta's environmental laws, and also eliminates duplication among existing Acts.

http://www.eub.gov.ab.ca/bbs/default.htm
The Alberta Energy and Utilities Board (EUB) is an independent, quasi-judicial agency of the Government of Alberta. Our mission is to ensure that the discovery, development, and delivery of Alberta's resources take place in a manner that is fair, responsible, and in the public interest.

http://www3.gov.ab.ca/env/protenf/approvals/factsheets/compuls.html
An important part of Alberta Environment's overall regulatory program is the compulsory monitoring that industry is required to undertake. This monitoring serves a number of purposes and assists both industry and the government.

http://www3.gov.ab.ca/env/protenf/approvals/factsheets/lead.html
The Alberta Leaders Environmental Approval Document (LEAD) Program provides an alternative regulatory framework for dealing with industrial activities. This framework is an option to the command and control approach that Alberta Environment currently uses. The LEAD program offers to good environmental performers the recognition and the regulatory flexibility that goes with the public trust that they have earned.

http://www3.gov.ab.ca/env/protenf/legislation/factsheets/pesticid.html
Pesticide Sales, Handling, Use and Application Regulation (AR 24/97). The Environmental Protection and Enhancement Act (EPEA) deals with various aspects of pesticide use within Alberta, including handling, sales and application.

http://www3.gov.ab.ca/env/protenf/pesticide/registra/
The Environmental Code of Practice for Pesticides provides detailed direction for pesticide sales and use in Alberta.

http://www.agric.gov.ab.ca/Sdepartment/deptdocs.nsf/all/epw8746
The Agricultural Operation Practices Act: Application and approval process. It is now the job of the NRCB to make the decisions on the construction and expansion of confined feeding operations (CFOs).

http://www3.gov.ab.ca/srd/land/pdf/PPD_2002.pdf
Policy and Procedures Document for Submitting the Geophysical Field Report Form (GFR), which is required for all applications on public land in the Green and White Areas of Alberta, including land administered by Alberta Parks and Protected Areas, Sustainable Resource Development.

Environmental Management

http://www.mrbb.ca/
The Mackenzie River Basin Board was created in 1997 by the Transboundary Waters Master Agreement between the Government of Canada, Saskatchewan, Alberta, British Columbia, Yukon and Northwest Territories. The purpose of this website is to help ensure that the public is informed and involved in issues concerning the Mackenzie River Basin.

http://www.ceamf.ca/01_who/01_CEAMstrategy.htm
The Northwest Territories (NWT) Cumulative Effects Assessment and Management (CEAM) Strategy and Framework is a collaborative effort to improve environmental management and stewardship in Canada's Northwest Territories.

http://www.cemaonline.ca/
The Cumulative Environmental Management Association (CEMA) is a multi-stakeholder initiative in northeastern Alberta (Canada) working to manage the cumulative environmental impacts of industrial development in the region. As a regional initiative for enhanced environmental protection of our natural environment, CEMA provides a forum for all stakeholders to discuss and resolve environmental issues related to industrial development in the Wood Buffalo region of Alberta.

http://www3.gov.ab.ca/env/irm/index.html
Integrated Resource Management (IRM) can be defined as a way of using and managing the environment and natural resources to achieve sustainable development. Using an IRM approach means that environmental, social and economic issues are considered, while finding ways for all uses to exist together with less conflict. IRM is based on: cooperation, communication, coordination, consideration of all values, and involvement of those potentially affected before action.

http://www1.agric.gov.ab.ca/Sdepartment/deptdocs.nsf/all/aesa6422
The AESA Program is a long-term, provincially funded program to facilitate the continued development and adoption of management practices and technologies that make agricultural production and processing more environmentally sustainable.

http://www.wbea.org/
The Wood Buffalo Environmental Association (WBEA) is a community-driven, non-profit organization made up of environmental and Aboriginal groups, government and industry. WBEA's mandate is to conduct air quality, ecosystem and human health effects monitoring in the Regional Municipality of Wood Buffalo.

http://www3.gov.ab.ca/env/protenf/standards/labdata.html
Good environmental management depends on accurate and reliable environmental information. This information includes monitoring data obtained from the analysis of air, water, wastewater, waste, soil and other samples by analytical laboratories. Alberta Environment is implementing the Laboratory Data Quality Assurance (LDQA) Policy to ensure that laboratory data submitted to the Department is accurate and reliable.

http://www.gov.nt.ca/RWED/pas/index.htm
Government of the Northwest Territories Protected Areas Strategy (PAS) promotes a balanced approach to land use decisions by incorporating the best available traditional, ecological, cultural and economic knowledge. It is consistent with all land claim, treaty entitlement and self-government agreements.

http://nwri.ca/
National Water Research Institute, Environment Canada. Canada's preeminent freshwater research facility. NWRI extends its influence across Canada and beyond, leading world-class research on freshwater issues.

http://www.ab-conservation.com/index2.asp
ACA is a non profit, non government association working collaboratively to conserve and enhance Alberta's wildlife, fisheries and habitat.

Contaminants

http://www.pops.int/
Stockholm Convention On Persistent Organic Pollutants (POPs). The Stockholm Convention is a global treaty to protect human health and the environment from persistent organic pollutants (POPs).

http://www.cec.org/programs_projects/pollutants_health/smoc/pdfs/Hgnarap.pdf
The North American Regional Action Plan (NARAP) on Mercury is one of a number of such regional undertakings that stem from the North American Agreement on Environmental Cooperation (NAAEC) between the governments of Canada, Mexico and the United States of America. As a parallel side agreement to the North American Free Trade Agreement, the NAAEC came into force on 1 January 1994 as an overarching framework for environmental cooperation.

http://www.ainc-inac.gc.ca/ncp/abt/bro_e.html
The Northern Contaminants Program (NCP) was created through consultation with the scientific community, Northern Aboriginal organizations, Northern communities, and government departments to examine the issue of contaminant levels on the environment and people in the Canadian North.

Air

http://www.casadata.org
The Alberta Ambient Air Data Management System (AAADMS), more commonly known as the CASA Data Warehouse, is a central repository for air quality data collected in Alberta. In Alberta, a comprehensive network of stations operated by Alberta Environment, air quality management zones, Environment Canada and industry monitors' air quality.

http://www.casahome.org/index.asp
The Clean Air Strategic Alliance (CASA) was established in March 1994 as a new way to manage air quality issues in Alberta. CASA is a non-profit association composed of diverse stakeholders from three sectors – government, industry, and non-government organizations such as health and environmental groups. CASA is a stakeholder partnership that has been given shared responsibility by its members, including the Alberta Government, for strategic air quality planning, organizing, and coordinating resources, and evaluation of results in Alberta through a collaborative process.

http://www.ijc.org/rel/agree/air.html
Agreement Between the Government of Canada and the Government of the United States of America on Air Quality.

http://www.unece.org/env/lrtap/lrtap_h1.htm
The 1979 Geneva Convention on Long-range Transboundary Air Pollution is one of the central means for protecting our environment. It has, over the years, served as a bridge between different political systems and as a factor of stability in years of political change. It has substantially contributed to the development of international environmental law and has created the essential framework for controlling and reducing the damage to human health and the environment caused by transboundary air pollution. It is a successful example of what can be achieved through intergovernmental cooperation.

http://www.unece.org/env/lrtap/multi_h1.htm
The 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone.

http://www.ec.gc.ca/international/multilat/l-hm_e.htm
Protocol to the UNECE Convention on Long-Range Transboundary Air Pollution (LRTAP) on Heavy Metals. The Protocol aims to cut emissions from industrial sources (iron and steel industry, non-ferrous metals industry), combustion processes (power generation, road transport), and waste incineration.

Oil Sands

http://www.conrad.ab.ca/
Canadian Oil Sands Network for Research and Development (CONRAD) is a research and development network which was established with the objective of encouraging, initiating and supporting collaborative research in oil sands. CONRAD is a network of companies, universities and government agencies organized to facilitate collaborative research in science and technology for Alberta Oil Sands.

http://www.gov.ab.ca/env/protenf/landrec/WetlandGuide.html
The Guideline for Wetland Establishment on Reclaimed Oil Sands Leases provides an approach to the development of wetlands on reclaimed landscapes in the oil sands region. It was developed by the Oil Sands Wetlands Working Group which had representation from government, industry, consulting, university and aboriginal communities.

http://www.osern.rr.ualberta.ca
The Oil Sands Reclamation Research Network is an initiative aimed at integrating and enhancing reclamation research and development activities. It is hosted at the University of Alberta by the Department of Renewable Resources, and sponsored by grants from the Oil Sands Industry with matching funds from government.

http://www.gov.ab.ca/env/regions/neb/rsds
Regional Sustainable Development Strategy for the Athabasca Oil Sands Area, developed in partnership with regional stakeholders, provides a framework and process for addressing the area's growing number of environmental issues, and for ensuring development is environmentally sustainable.

http://www.ramp-alberta.org/
Initiated in 1997, the Regional Aquatics Monitoring Program (RAMP) is a joint environmental monitoring program that assesses the health of rivers and lakes in the Oil Sands Region of northeastern Alberta. The program is designed to identify and address potential impacts of oil sands development and is frequently adjusted to reflect monitoring results, technological advances and community concerns.

Habitat and Biodiversity

http://www.arc.ab.ca/whatsnew/newsreleases/northernwatershed.asp
Industry, government, the Alberta Conservation Association and the Alberta Research Council are mid-way through a four-year, $1.4 M research project to study the effects of disturbances on forest and fish resources in northwestern Alberta. The resulting research knowledge will help both industry and government address immediate concerns related to increasing development, and will contribute to the long-term planning and management of northern Alberta's forest and aquatic resources.

http://www.nce.gc.ca/nces-rces/sfm_e.htm
Networks of Centres of Excellence, Sustainable Forest Management (SFM) Network provides research support for the development of total management protocol for Canada's boreal forest. This includes creating environmental technologies and management strategies to sustain all values inherent in the boreal forests and maintain them in all their physical, biological, ecological and economic dimensions for future generations.

http://www.ducks.ca/research/
The Institute for Wetland and Waterfowl Research (IWWR) serves as Ducks Unlimited's respected science and research arm. The IWWR's mission is to help guide the conservation of waterfowl and wetlands by developing and sustaining a premier program of research and by cultivating skilled professionals in wetland and waterfowl conservation biology.

http://www.ab-conservation.com/
Alberta Conservation Association (ACA) is a non profit, non government association working collaboratively to conserve, protect and enhance Alberta's wildlife, fisheries and habitat.

http://www.nawmp.ab.ca/
In 1986, Canada and the United States signed the North American Waterfowl Management Plan (NAWMP), the most wide-ranging land use and wildlife habitat program in the world. Joined by Mexico in 1994, the NAWMP's goal is to return waterfowl populations to their average 1970s levels by conserving wetland and upland habitat.

http://www.nawmp.ab.ca/AlbertaWetlandsGuide.pdf
Alberta's Wetlands: A Law and Policy Guide. The purpose of this Guide is to give users familiarity with the various laws and policies that may affect the condition or existence of Alberta's wetlands. The Guide focuses on the information needs of "wetland managers", meaning persons or agencies with an interest in the continuing existence of wetlands and in protecting them.

http://www.ducks.ca/conservator/192/boreal.html
Ducks Unlimited Canada's Western Boreal Forest Initiative (WBFI) was launched in the summer of 1997 to take a good, hard look at the factors affecting this immense landscape. It's a region that ranks third of the 25 most important and threatened waterfowl habitat areas on the continent

http://www3.gov.ab.ca/srd/fw/fishing/mi.html
Alberta Sustainable Resource Development articles and web sites on fisheries management issues and programs, including the *Fish Conservation Strategy for Alberta*.

http://www.pnr-rpn.ec.gc.ca/nature/ecosystems/da00s02.en.html
Selected Environment Canada Programs in the Boreal Ecosystem, including the Western Boreal Conservation Initiative.

http://www.speciesatrisk.gc.ca/legislation/default_e.cfm
Environment Canada Species At Risk page includes links to federal acts concerning species at risk.

http://www3.gov.ab.ca/srd/forests/fmd/legacy/legacy.html
The Alberta Forest Legacy sets out a management approach that reflects citizens' desire to maintain, on provincially-owned land, their access to the diverse economic, cultural and recreational benefits that are provided by, and dependent upon, sustainable forest ecosystems.

Water Resources

http://www.cwn-rce.ca
The Canadian Water Network/Réseau canadien de l'eau (CWN/RCE) is a federally funded Network of Centres of Excellence. The CWN/RCE was formed to identify and address critical issues facing our nation in connection with the provision of clean water and to provide the foundation for development of a national vision for Canada's role in the effective management and use of our water resources.

http://www3.gov.ab.ca/env/water/Legislation/Framework_Text_Only.pdf
The Framework for Water Management Planning outlines the process for water management planning and the components required for water management plans in the province. It applies to all types of waterbodies, including streams, rivers, lakes, aquifers and wetlands, and takes a holistic approach. The Framework recognizes that no two situations are exactly alike and therefore is not intended to be a detailed user's manual on how to prepare water management plans. Rather, it is meant to provide general guidance for the planning process.

http://www.msc-smc.ec.gc.ca/wsc/index_e.cfm?cname=main_e.cfm
Water Survey of Canada, National Water Quantity Survey Program. The Water Survey of Canada is the national agency responsible for the collection, interpretation and dissemination of standardized water resource data and information in Canada.

Environmental Assessment

http://nwt-tno.inac-ainc.gc.ca/index_e.htm
In the Northwest Territories, the Department of Indian Affairs and Northern Development (DIAND) has a wide variety of responsibilities. Land, water and resource management are coordinated through the region's operational directorates which include: Mineral and Petroleum Resources, Pipeline Readiness Office, Operations, Giant Mine Remediation Project Team and Renewable Resources and Environment.

http://www.mveirb.nt.ca/
The Mackenzie Valley Environmental Impact Review Board (MVEIRB) is responsible for conducting environmental assessments of developments which are referred to it. The Canadian Environmental Assessment Act (CEAA) no longer applies in the Mackenzie Valley, except in very specific situations. The Review Board will recommend ways to protect the environment from impacts caused by a development. It can also recommend to the Minister of Indian Affairs and Northern Development that a development be rejected because the impacts are too great.

http://www.taiga.net/wmac/ifa/ifa_enimpactscreening.html
Environmental Impact Review Board (Inuvialuit Settlement Region) – Environmental Impact Screening and Review Process.

http://www.ec.gc.ca/eem/english/default.cfm
Environmental Effects Monitoring (EEM) is a science-based tool that can detect and measure changes in aquatic ecosystems (i.e., receiving environments) potentially affected by human activity (i.e., effluent discharges).

http://www3.gov.ab.ca/env/protenf/publications/SurfWtrQual-Nov99.pdf
This document compiles surface water quality guidelines for use in Alberta. It updates and replaces the Alberta Surface Water Quality Guidelines: A Working Compendium of July 1998 (AEP 1998a) and is the latest edition in an ongoing process of development, review, and compilation of water quality guidelines. It also replaces Appendix 8 of the Water Quality Based Effluent Limits Procedure Manual (AEP 1995) and Section 3 of A Comparison of Alberta's Environmental Standards to those of Other North American Jurisdictions (AEP 1999).

Drinking Water

http://www.hc-sc.gc.ca/hecs-sesc/water/dwgsup.htm
Guidelines For Canadian Drinking Water Quality - Supporting Documents. Health Canada has published Guidelines for Canadian Drinking Water Quality since 1968. The guidelines are prepared by the Federal-Provincial-Territorial Committee on Drinking Water: the Committee is made up of representatives from each province and territory, as well as from Health Canada.

http://www.pws.gov.nt.ca/pdf/WaterAndSanitation/WaterFramework.pdf
Managing Drinking Water Quality in the NWT - A Preventative Framework and Strategy (December 2003) outlines actions the Government of the Northwest Territories is working on to promote safe drinking water in the NWT.

http://www.pws.gov.nt.ca/water/waterq_main_menu.asp
Public access to community water quality data records for chemical and biological water quality data, including values for the Guidelines for Canadian Drinking Water.

http://www.pws.gov.nt.ca/pdf/GEP/contents.pdf
Good Engineering Practices for Northern Water and Sewer Systems outlines best practices for communities based on information gained from northern experience.

GLOSSARY

11-ketotestosterone: A male steroid hormone that researchers use to determine reproductive problems in fish.

17β estradiol: a hormone responsible for developing yolk protein in fish eggs.

Accredited: A laboratory becomes accredited when it meets certain specifications for accuracy, reliability and methods. Accreditation is usually done by government or non-partial organizations.

Adsorbable organic halides (AOX): a standard analytical procedure that measures mainly chlorinated organic compounds. This procedure gives no information on the source or nature of the compounds present or their toxicity. It has the advantage of being simple to measure. Although some AOX occurs naturally, these compounds can be high in treated effluent from bleached kraft pulp mills and to a lesser extent municipal sewage.

Algae: simple plants that grow in water. Unlike land plants, most of them have no stems, roots or leaves. They can grow on the bottom of rivers or suspended in water.

Allocation: an amount of water set for a particular use. Agricultural, industrial and municipal water users apply to Alberta Environment for a licence to divert or use a set amount of water. It does not apply to domestic use. The water allocation outlines the volume, rate and timing of a diversion of water.

Ammonia: a molecule composed of nitrogen and hydrogen. As a gas, it can be poisonous. It is the basis for some fertilizers, but certain forms can kill fish if it gets into water.

Anoxic: without oxygen.

Approval: a permit issued to operate municipal facilities and industries.

Approval limits: the maximum quantity or concentration of specific chemicals that a company or municipality is allowed to release in their effluents to surface water. Same as release limit.

Atmospheric deposition: chemicals transported by air currents (sometimes for long distances) and deposited on land or in water. Wet deposition is from precipitation, dry is as particles or gases.

Baseflow: the flow in a stream that does not come from either snowmelt or rainstorm runoff. It may be supported by groundwater seepage.

Basin: a geographic area drained by a single major river, including its tributaries, lakes and other water bodies. Same as watershed.

Benthic invertebrates: aquatic animals without backbones that live on the bottom of rivers and lakes. Examples are mayfly nymphs, aquatic earthworms and crayfish.

Bioaccumulate: the increase in concentration in the tissues of living organisms because they cannot use or excrete the entire amount they take in.

Bioavailable: The portion of a nutrient (or other chemical) that can be absorbed, transported, and used by organisms for their growth.

Biochemical oxygen demand (BOD): a measure of the quantity of dissolved oxygen needed to decompose organic matter by bacteria. Generally, the greater the BOD, the more polluted the water.

Biodiversity: the variety of life. The number of different types of living organisms, including bacteria, animals and plants within an ecosystem.

Biomarker: a particular measurement used to indicate the amount of toxic effect in a plant or animal.

Biomass: the total quantity of living matter within a given unit of environmental area. Usually expressed as kilograms per area or amount of water.

Bitumen: a general term for solid or semi-solid hydrocarbons. Also called tar. Gasoline and other products are made from it.

Calibration: the process of adjusting numerical or physical modelling conditions in a computer model for the purpose of improving agreement with experimental data.

Chemical: the makeup of all matter. For example, water is a chemical (H_2O), and organic chemicals make up all life.

Chlorinated organics: compounds that have chlorine atoms as well as hydrogen and carbon atoms; some also have oxygen atoms attached. Many of these are used as insecticides, such as DDT, chlordane, mirex and toxaphene. Dioxins and furans are chlorinated organics.

Chlorophyll *a*: a pigment that plants use for photosynthesis. It can be extracted from samples of algae and used as a measure of the amount of plant material present.

Climate: a combination of all elements that characterize the atmosphere. Often used to describe the state of the atmosphere at a given place or over a period of time.

Climate change: a long-term change in the average weather of a region.

Compliance: how well a company or municipality meets concentrations or quantities of specific substances or conditions in an approval.

Concentration: the amount of a substance in a known amount of water or air. For example, a concentration may be measured as milligrams of substance per litre of water (this is the same as parts per million).

Contaminant: a substance in water, air or soils that is not normally present. Usually used for substances of concern for aquatic or human health, although it may include naturally occurring substances.

Continuous flow centrifugation: a technique that uses a centrifuge to extract suspended sediment (or suspended particles) from river water. River water is pumped continuously through it, and the suspended sediments and chemicals bonded to them can be separated from the water. Then the water and sediment can be analyzed separately.

Control: the natural state, as compared with an experimental state. For example, in a mesocosm, one part is natural river water without anything added (the control). The other parts have things like pulp mill effluent added, and scientists can compare the effects between the control and treatment parts on fish and other organisms.

Cumulative effects: The environmental impact of a human activity in combination with the impacts of other human activities. By itself, the impact from a particular activity may not be noticeable, but when all impacts are considered, there could be a serious effect.

Cumulative effects assessment (CEA): the assessment or measurement of multiple effects from human activities.

Delta: land composed of sediments deposited at the mouth of a river. As the sediments carried by flowing water reach quiet water, as in a lake, the sediments drop out.

Dioxins and furans: Popular names for two classes of chlorinated organic compounds, known as polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs); both dioxins and furans are formed either as by-products during some types of chemical production that involve chlorine and high temperatures or during combustion where a source of chlorine is present.

Discharge: the flow of water in a river, stream or effluent over a given time period.

Dissolved oxygen (DO): the concentration of oxygen dissolved in water and readily available to aquatic life. Usually expressed as milligrams of oxygen per litre of water.

Ecology: the study of the inter-relationships among living things and their environment.

Ecoregion: a continuous geographic area in which the climate, soils, etc. are similar and therefore have similar plants and animals.

Ecosystem: a community of animals, plants and bacteria and their chemical and physical environment. An ecosystem can be as small as a puddle of water, although the word usually refers to larger landscapes.

Effluent: wastewater discharged to a stream, usually from a pipe.

Elemental chorine-free bleaching: a pulping process that uses chlorine dioxide to bleach pulp, rather than elemental chlorine. This prevents the formation of dioxins and furans.

Emergence: in insects, the change from an aquatic immature form to a flying adult.

Emissions: gases, particulates and a variety of chemicals given off by industrial processes.

Endocrine disruption: reproductive impairment because certain chemicals mimic natural hormones. These chemicals bind to hormone receptors and prevent or interfere with natural reproductive processes.

Endpoints: measurement or assessment goals. Examples are levels of specific chemicals, fish gonad size and hormone levels.

Environmental effects: harmful effects on the environment from human activities.

Environmental indicators: Physical, chemical or biological features that can be monitored and used to measure changes in the environment.

Enzyme: any of many proteins produced by living organisms, which act to increase the speed of certain living functions. For example, enzymes help us digest food.

Eutrophication: the degradation of water quality due to enrichment by nutrients (usually phosphorus and nitrogen).

Gonad: male or female reproductive organs.

Habitat: the specific surroundings where a plant or animal lives. Habitat includes food, shelter and water.

Hydrocarbons: organic chemical compounds that contain only carbon (C) and hydrogen (H) atoms. Many oils, fats, waxes, solvents and paraffin are either hydrocarbons or contain large hydrocarbon subunits. Hydrocarbons and their chemical derivatives are often quite flammable. Many are toxic or present other health hazards.

Hydrology: the science of water - its properties, movement, laws and distribution.

Hydrometric: measurement of water, usually of such properties as flow, depth and width.

Kraft pulp mill: establishments primarily engaged in manufacturing pulp from wood or other material, using chemical methods. *Kraft* pulp is chemical pulp obtained from the sulphate or soda processes.

Ligand: A molecule that binds to another molecule, used especially to refer to a small molecule that binds specifically to a larger molecule. For NREI, it usually means a hormone that binds to a receptor.

Lignin: A component found in trees and plants that is largely responsible for the strength and rigidity of plants. Because it is believed to contribute to the chemical breakdown of paper, it can be removed during the manufacturing process to increase the life and stability of the paper. Newspaper is a good example of paper with lignin present: it quickly yellows and becomes brittle.

Load: a quantity of a substance entering a river or stream in a particular time period. For example, a municipal sewage treatment plant contributes 20 kilograms of phosphorus per day.

Model: a computer program used to describe and make predictions about natural events.

Morphology: the look or shape of living or nonliving things.

Nanogram: one billionth of a gram, or 1/1,000,000,000.

Nitrogen oxide (NO_X): a chemical produced from burning fossil fuels, including gasoline and coal. Nitrogen oxides react with volatile organic compounds to form smog. Nitrogen oxides are also major components of acid rain.

Nutrient: a substance essential for the growth of living organisms. In water, it usually refers to nitrogen and phosphorus, the same chemicals used to make a garden grow.

Organic chemicals: compounds that have carbon atoms linked by carbon-carbon bonds. All living matter is organic. Many organic chemicals are natural, but humans make some, such as pesticides.

Overbank: water that flows over a stream's natural banks.

Oxygen delignification: A stage preceding bleaching in the production of bleached kraft pulp, which involves treating the pulp with oxygen to wear down the lignin binding fibers.

Perched basin: a lake or pond perched above and not connected to the main groundwater flow systems.

Persistent Organic Pollutants (POP): chemical substances that stay in the environment, bioaccumulate through the food web, and may cause harm to human health and the environment.

Pesticide: any chemical used to control unwanted organisms. A herbicide kills plants, an insecticide kills insects.

Pollution: the contribution of substances from human activities that may make the environment less suitable for desired uses.

Polychlorinated biphenyls (PCBs): a group of chemicals made by humans that are stable, non-corroding, fire resistant, toxic and relatively non-biodegradable. They were once used in electrical transformers because of these properties and in paint. They are frequently found in industrial wastes, and therefore in surface water and groundwater. They accumulate in the environment, particularly in the sediment where they can remain indefinitely. They were virtually banned worldwide in 1979, but continue to be present in the flesh of fish and other animals.

Polycyclic aromatic hydrocarbon (PAH): a class of very stable organic molecules. They are found in petroleum products, and are formed by the incomplete combustion of wood and fuels. Some of them bioaccumulate in plants or animals. An example is naphthalene.

Pore water: the water surrounding individual grains of sediment in a river or lake bottom.

Recharge: the process by which precipitation makes its way into groundwater.

Reclamation: the process of converting disturbed land to its former uses. This is different than restoration, which is the process of restoring site conditions to what they were before the land was disturbed.

Reference condition: the natural condition. Scientists cannot know the impact of a particular development unless they know what conditions were there before the development went in. Sometimes river water upstream of a development is compared with downstream water – the upstream water is called "reference" conditions.

Relationship: a relationship is present when as one factor changes, another does as well. For example, it was assumed that when levels of dissolved oxygen in the water above the sediments changed, levels in the porewater would match this change.

Residual: the material that remains. In forestry, it applies to trees left behind after harvesting.

Riparian: habitat near streams, wetlands or lakes.

Runoff: Water that moves across (or through) soils on the land during snowmelt or rainstorms.

Sediments: soil particles that have been transported from their original location by wind or water. They may be in suspension or settled to the bottom of a river, lake or delta.

Seiche: a wave on the surface of a lake caused by wind. It can make the water level higher on the downwind side.

Selenium: a naturally occurring element found in soils (and water and air). It is a necessary nutrient in very small amounts, but it can be toxic in high doses.

Steam assisted gravity drainage (SAGD): a process to recover bitumen from oil sands. It Consists of continuous injection of steam into the oil sands through a horizontal injector well. The steam lowers the viscosity of crude bitumen enough that it drains into a lower production well, where it can be extracted.

Stressors: anything that causes stress to a population of organisms or an ecosystem. Examples are certain organic chemicals, excess nutrients or high temperatures.

Substrate: the physical surface on which an organism lives.

Sulfur: A nonmetallic element that exists in many forms including yellow crystals. Sulfur is used to make medicines, rubber, matches, chemicals and many other products. It is one of the elements present in varying quantities in coal.

Sulfur dioxide (SO_2): a colorless, irritating gas that is a primary cause of acid rain. It is a byproduct of coal combustion.

Sustainable: management practices that do not take more from an ecosystem than it can provide. If a resource is being used in a sustainable way, it should last forever.

Tailings: waste material from industrial excavations.

Topography: the general configuration of the land surface, including elevation and position of objects.

Total suspended solids (TSS): all of the particles in the water. Water with high TSS levels appears cloudy or turbid. These particles may include silt, clay, fine organic or inorganic matter and microscopic organisms.

Toxic: poisonous or harmful.

Transboundary: having a source in one country but entering another country. Usually refers to air pollutants.

Vitellogenin: egg yolk protein normally produced in the liver of female fish. Its presence in the blood plasma of male or immature fish has gained acceptance as an indicator of exposure to chemicals that can mimic the receptor binding properties of the female reproductive hormone 17ß-estradiol.

Volatile organic compounds (VOCs): organic chemicals that easily move from water into air. Examples are solvents and fuels.

Water column: water from the surface to the bottom of a lake or river.

Water quality: the chemical, biological and physical characteristics of water, usually with respect to its suitability for a particular purpose.

Water quality guideline: a concentration or statement for a substance or characteristic that can be compared with that substance in water. It is assumed that if the guideline is exceeded, there could be risk to aquatic life or other uses.

Watershed: land that drains water toward a water body.

Wood furnish: the wood used in a pulp mill to make pulp.

APPENDIX. CONTAMINANTS

Dioxins and Furans

(from Health Canada's Its Your Health website)

All dioxins and furans have the same basic chemical "skeleton", and they all have chlorine atoms as part of their make-up. There are 210 different dioxins and furans. The one considered most toxic is a dioxin called **2,3,7,8,-TCDD.** Dioxins and furans are created and released into the environment as the by-products of specific activities. For example, we create dioxins and furans when we burn garbage and fuel.

The biggest source of dioxins and furans in Canada is the large-scale burning of municipal and medical waste. Other major sources include:

- The production of iron and steel
- The backyard burning of household waste, especially plastics
- Wood burning, especially if the wood has been chemically treated
- Fuel burning, including diesel fuel and fuel for agricultural purposes and home-heating
- Electrical power generation

Dioxins and furans can travel long distances in the atmosphere, so we may be exposed to dioxins and furans that are created in other parts of the world. These substances work their way up the food chain by dissolving and remaining stored in the body fat of animals. Because of this, we actually take more dioxins and furans into our bodies through food than through air, water or soil. Meat, dairy products, and fish have higher levels of dioxins and furans than fruits, vegetables and grains.

The health risks of exposure to any toxic substance depend on a number of factors, including the dose, the duration, how you are exposed, your general health and habits, and whether other chemicals are present.

According to the scientific evidence available now, current levels of dioxins and furans in our food, air, water and soil are so low that they pose no serious health threat to most of us. However, there may be health risks for certain groups, including people who eat large amounts of fish that contain high levels of dioxins and furans.

Scientists have researched the effects of large doses of dioxins and furans on laboratory animals. While the impact varies from one type of animal to the next, serious health effects that occur include weight loss, skin disorders, liver problems, birth defects and cancer. There is not enough evidence available to say for certain whether large doses would have similar effects on people. However, scientists agree that our exposure to dioxins and furans should be kept as low as possible.

Polychlorinated Biphenyls (PCBs)

(from Health Canada's Its Your Health website)

PCBs are a class of manufactured chemicals that tend to last for many years. They do not break down easily on their own, and they are difficult to destroy. Little is known about the long-term health effects of PCBs, so it is important to keep our exposure to these chemicals as low as possible.

From the 1930s to the 1970s, PCBs were widely used as ingredients in a number of industrial materials, including sealing and caulking compounds, inks and paint additives. They were also used to make coolants and lubricants for certain kinds of electrical equipment, including transformers and capacitors.

By 1977, concern about the impact of PCBs on the environment led to a North American ban on manufacturing and importing PCBs. However, the ban did not cover existing PCBs that were used in electrical applications. Those are being phased out now, and the federal government has set strict guidelines for the storage and disposal of PCBs.

Small amounts of PCBs are found in the environment all over the world. There are also traces of PCBs in our food and in our own bodies. PCBs move up the food chain by getting into the body fat of animals and staying there for a long time.

Larger concentrations of PCBs are found in certain types of electrical equipment, and at storage sites across the country, which contain PCBs that have been collected for disposal. An uncontrolled fire at one of the storage sites could release large amounts of PCBs into the environment.

Scientists do not know much about the long-term impact of PCBs on human health. Most of what is known about the health risks of PCBs is based on observations of people who were exposed briefly to high levels as a result of accidents or job-related activities. This kind of exposure is known to cause a variety of conditions, such as severe acne, numbness in the arms or legs, muscle spasms and problems with the nervous system.

There have also been suggestions that workplace exposure to high levels of PCBs over a long period of time may increase a worker's chance of getting cancer – especially cancer of the liver and kidney. However, there is no proof yet of a definite link between PCBs and cancer.

Fortunately, most Canadians are not exposed to high levels of PCBs. For most, exposure to PCBs is limited to the very low levels found in food and the environment. These levels are not likely to cause health problems.

There may be health risks for specific groups of people who eat large amounts of sport fish or game contaminated by PCBs. These higher risk groups include Aboriginal peoples and the families of people who hunt and fish for food. More research is needed before scientists can say exactly how exposure to low levels of PCBs will affect human health over the long term.

Mercury

(from Environment Canada websites)

Mercury is listed as a "toxic substance" under the Canadian Environmental Protection Act. It is a liquid heavy metal that can volatize into the air and be carried by the atmosphere all over the world. In Canada, airborne mercury emissions come mainly from coal-fired power plants in the United States and base metal smelting plants and incinerators in Canada.

Scientists have concluded that in Canada and the United States, mercury originates from both domestic and international sources and is deposited in sensitive ecosystems. Mercury is found in many lakes, streams, forests and fields. It can convert to a very toxic and bioaccumulative form known as methylmercury – a substance that can affect both humans and wildlife. For example, methylmercury levels in traditional foods in northern Canada are rising above those established as acceptable by the World Health Organization.

When mercury from natural and human sources is released to the atmosphere, it may be transported from its point of origin and enter the global mercury cycle to be deposited in aquatic and terrestrial ecosystems. Converted by bacterial action in lakes and waterways to the more toxic form known as methylmercury, it then bioaccumulates in fish and shellfish. Bioaccumulation is the process by which a substance builds up in a living organism from the surrounding air or water, or through the consumption of contaminated food. Methylmercury gets concentrated as it is transferred up the food chain to birds, animals, marine mammals and humans in a process known as biomagnification. Through this cycle, mercury can contaminate entire food webs, posing a serious threat to ecosystem health and particularly to the higher order species in the food chain.

High levels of any mercury exposure for humans can cause severe health problems immediately, but it is the accumulation of low quantities of mercury that is the greater risk to future mothers and their babies. In most chemical forms, mercury is a neurotoxin – this means it can cause damage to the brain and central nervous system. It also affects the kidneys and lungs. Methylmercury, one of the most toxic forms of mercury, is known to affect learning ability and neuro-development in children.

Polycyclic Aromatic Hydrocarbons (PAHs)

(from Clean Air Strategic Alliance website)

Polycyclic aromatic hydrocarbons (PAHs) are a class of chemicals that are formed during the incomplete combustion of gasoline, diesel, oil, coal, wood, garbage or other organic substances. Tobacco smoke and charbroiled meats are common sources of PAHs. Other outdoor sources of PAHs include vehicle exhaust emissions, wood smoke from fireplaces, smoke from forest fires and industrial facilities.

There are more than 100 different PAHs with varying levels of toxicity. PAHs usually occur as complex mixtures (contained in soot and smoke) rather than single compounds. PAHs occur in the atmosphere in the vapour phase or attached to dust particles. People can be exposed to PAHs through breathing, eating or drinking substances that contain PAHs. Exposure can also take place through skin contact.

Air quality guidelines for PAHs are usually established in jurisdictions where PAHs are of concern because of significant sources such aluminum smelters, residential wood burning, open air burning or diesel motor vehicles. Alberta does not have guidelines for ambient concentrations of PAHs.

Sulphur Dioxide (SO_2)

(from Canadian Centre for Occupational Health and Safety website)

Sulfur dioxide is a colourless gas with a pungent, irritating odour similar to burning sulfur. It is a colourless liquid below -10°C. Sulfur dioxide will not burn. Cylinders or tanks of compressed SO_2 may rupture and explode if heated. It is very toxic and may be fatal if inhaled. Sulfur dioxide is also extremely irritating to eyes and respiratory tract. It causes lung injury and these effects may be delayed. It may also cause frostbite.

Its major use is a captive intermediate in the production of sulfuric acid. In the pulp and paper industry, sulfur dioxide is used to produce other chemicals such as chlorine dioxide and sodium hyposulfite and is also used in the bleaching of pulp. In food processing, sulfur dioxide is used for fumigating, preserving, bleaching and steeping. It is also used to reduce residual chlorine in potable water, treated sewage and industrial effluent, as an oxygen scavenger, a selective extraction solvent and as a catalyst in chemical processes. In the presence of a catalyst (e.g. nitrogen compounds), sulfur dioxide can be oxidized to sulfuric acid. It occurs as a by-product during the burning (combustion) of sulfur containing organic compounds (e.g. coal). A common component of air pollution, it is a major contributor to acid rain.

Nitrogen Oxides (NO_X)

(from Alberta, Naturally and Alberta Community Development, Cultural Facilities and Historical Resources Division)

Oxides of nitrogen are produced by high temperature combustion of fossil fuels. Nitrogen oxide is the most common form of these oxides but it quickly converts to nitrogen dioxide (NO_2) on exposure to the atmosphere. NO_2 is a reddish-brown coloured gas with a strong smell. It causes acid rain and can cause respiratory problems in people. It also helps produce ground level ozone, a major component of smog. Alberta Environment guidelines for NO_2 are an average of 210 parts per billion (ppb) over 1 hour, 110 ppb over a 24-hour period and annual averages of 30 ppb.

In Alberta well over 40% of emissions of oxides of nitrogen come from transportation sources, primarily cars. Just less than 20% comes from power plants and about 35% from industrial sources. Oxides of nitrogen are measured using chemiluminescence: nitrogen oxide mixed with ozone will produce nitrogen dioxide, oxygen and light – the more light that is produced, the higher the concentration of oxides of nitrogen.

Pesticides

Pesticides are chemicals designed to kill a variety of pests such as insects (insecticides), unwanted plants or weeds (herbicides), fungi (fungicides) and rodents (rodenticides). Products used to kill bacteria and viruses are also classified as pesticides. These include disinfectants, cleansers, bleaches, toilet bowl cleaner, and mould and mildew remover.

Pesticides include not only man-made chemicals, but also naturally occurring chemicals, biological materials and mechanical, electric or electronic devices.

By design, pesticides are toxic to living organisms. Some pesticides are selective in that they will kill only a specific type of pest. For example, some herbicides work by interfering with photosynthesis, a process that only occurs in plants. For this reason, these herbicides will not affect humans or other animals. However, other pesticides are not as selective, and can be harmful to other organisms such as butterflies or humans.

Pesticides contain both "active" and "inactive" ingredients. The active ingredients are designed to kill the pests, while the inactive ingredients are added to dilute or dissolve the mixture in order to make it easier to use. By law, companies who make pesticides have to list the active ingredients on the label, but not all inactive ingredients have to be listed. Some inactive ingredients found in pesticides can be more harmful to the health of humans, pets or other organisms than the active ingredient. One example is benzene, which is known to cause cancer.
www.cec.org/files/pdf/POLLUTANTS

DDT

DDT was first registered in 1946 and used in Canada to control insect pests in crops as well as domestic and industrial applications. Most uses of DDT were phased out by the mid-1970s. All remaining uses were discontinued in 1985, although existing stocks could be used until 1990. One reason for allowing this was to avoid a large-scale disposal problem. It is still being used in other countries, mainly to kill mosquitoes that cause malaria and other diseases.

Although DDT has saved many lives, many environmental and health issues have arisen from its use. DDT is a persistent chemical – meaning it lasts for a long time in nature. Air and water currents can spread DDT over great distances. On warm days, it can slowly evaporate into the air and travel for long distances until it reaches cooler temperatures in the north. DDT can be absorbed by plants, wildlife and people. It is mostly stored in fat, and therefore animals that are naturally lean do not store much DDT. But it can biomagnify. When DDT was being used in the 1970s, birds of prey were laying eggs with shells so thin that they would break when the mothers sat on them. It is also believed that DDT can disrupt hormones and development in animals. In laboratory studies, DDT has been linked to liver cancer and adrenal gland problems in rats, and was found to affect the nervous system and reproduction. In humans, it is believed to cause cancers and affect the nervous system.

http://nwt-tno.inac-ainc.gc.ca/pdf/contaminants/DDT_E.pdf

Toxaphene

Toxaphene is a chlorinated organic pesticide often used as an insecticide. It was used on crops in the United States. Wildlife and people are exposed to toxaphene mostly through food. Fish are particularly sensitive to the effects of toxaphene. At levels much higher that typically found in the North, this pesticide can damage the kidneys, lungs, immune and nervous systems of humans. The use of toxaphene was restricted in Canada, the USA and western Europe in the early 1980s. It is still used on crops in some tropical countries. Toxaphene is transported northward from warmer regions of the globe. In warmer climates, it evaporates and moves with winds and weather for a distance. As it travels northward, it cools, condenses, then falls back to the earth.

http://nwt-tno.inac-ainc.gc.ca/pdf/contaminants/POPs_E.pdf